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An XCP User's Guide and Reference Manual

by Thomas B. Sanford, Eric A. D'Asaro, Eric L. Kunze, John H. Dunlap,
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Applied Physics Laboratory University of Washington
1013 NE 40th Street Seattle, Washington 98105-6698

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Acknowledgments

The XCP work done by the authors has been primarily funded by the Office of Naval Research. We thank Mark Morehead for his valuable contributions to the OCEAN STORMS project, Art Bartlett and Pat McKeown for their contributions to the success of many APL-UW XCP operations, and Dicky Allison for her help in this project. We would also like to acknowledge the support of the Oceanographer of the Navy (N096) through Ken Ferer of the Naval Research Laboratory's Tactical Oceanography Warfare Support Program Office (Code 7410) for development of the XCP. Publication of this work was funded by ONR.

ABSTRACT

This report describes expendable current profiler (XCP) instrumentation, equipment testing procedures, data acquisition methods, and data processing. It also provides a guide to XCP field operations.

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1. INTRODUCTION

The expendable current profiler (XCP) manufactured by Sippican, Inc., measures ocean velocity and temperature from the surface to a depth of 1500 m. This report discusses XCP instrumentation, equipment testing procedures, data acquisition methods, and data processing and provides a guide to XCP field operations. Software methods for fixing certain failure modes are also described.

1.1 Background

Studies of ocean dynamics and water transport require rapid and accurate observations of velocities. One way to measure these quantities is through naturally occurring electric currents induced by the motion of seawater through the Earth's magnetic field. The concept of measuring ocean currents from motionally induced electromagnetic (EM) fields was first suggested by Michael Faraday in 1832. More recently (in the early 1970's), the EM Group* at the Woods Hole Oceanographic Institution used EM principles to build a free-fall instrument called the Electro-Magnetic Velocity Profiler, or EMVP (Sanford et al., 1978). The EMVP was approximately 2.5 m long, weighed about 160 kg, and could achieve a complete velocity profile in 6000 m of water in about 3 hours. Experience with the EMVP suggested that a smaller, expendable version could be developed. In 1976, Thomas Sanford and Robert Drever began development of an expendable temperature and velocity profiler (XTVP), initially funded by the Office of Naval Research (ONR) and later by the Naval Ocean Research and Development Activity (now NRL at Stennis). In 1979, Sippican, Inc., began manufacturing the probes as expendable current profilers, or XCPs.

One advantage of the XCP is that it can be deployed from any sort of platform (ship, aircraft, ice, etc.), enabling rapid surveys, especially from aircraft. Moreover, it can be launched in any weather conditions, including hurricanes.

XCPs have been used in a variety of oceanographic programs. Figure 1 shows the locations where they have been deployed by University of Washington (UW) investigators. Some of the topics investigated using XCPs include mixed-layer dynamics, geostrophic eddies, the Mediterranean Outflow, Mediterranean Water eddies (Meddies), fronts, cold- and warm-core Gulf Stream rings, topographic interactions, near-inertial waves, surface waves, the Equatorial Undercurrent, and benthic boundary layer dynamics. XCPs have been deployed at latitudes ranging from the equator to 86°N. A comprehensive bibliography listing XCP references and studies using XCPs is given in Appendix A.

*Now at the Applied Physics Laboratory, University of Washington (APL-UW).

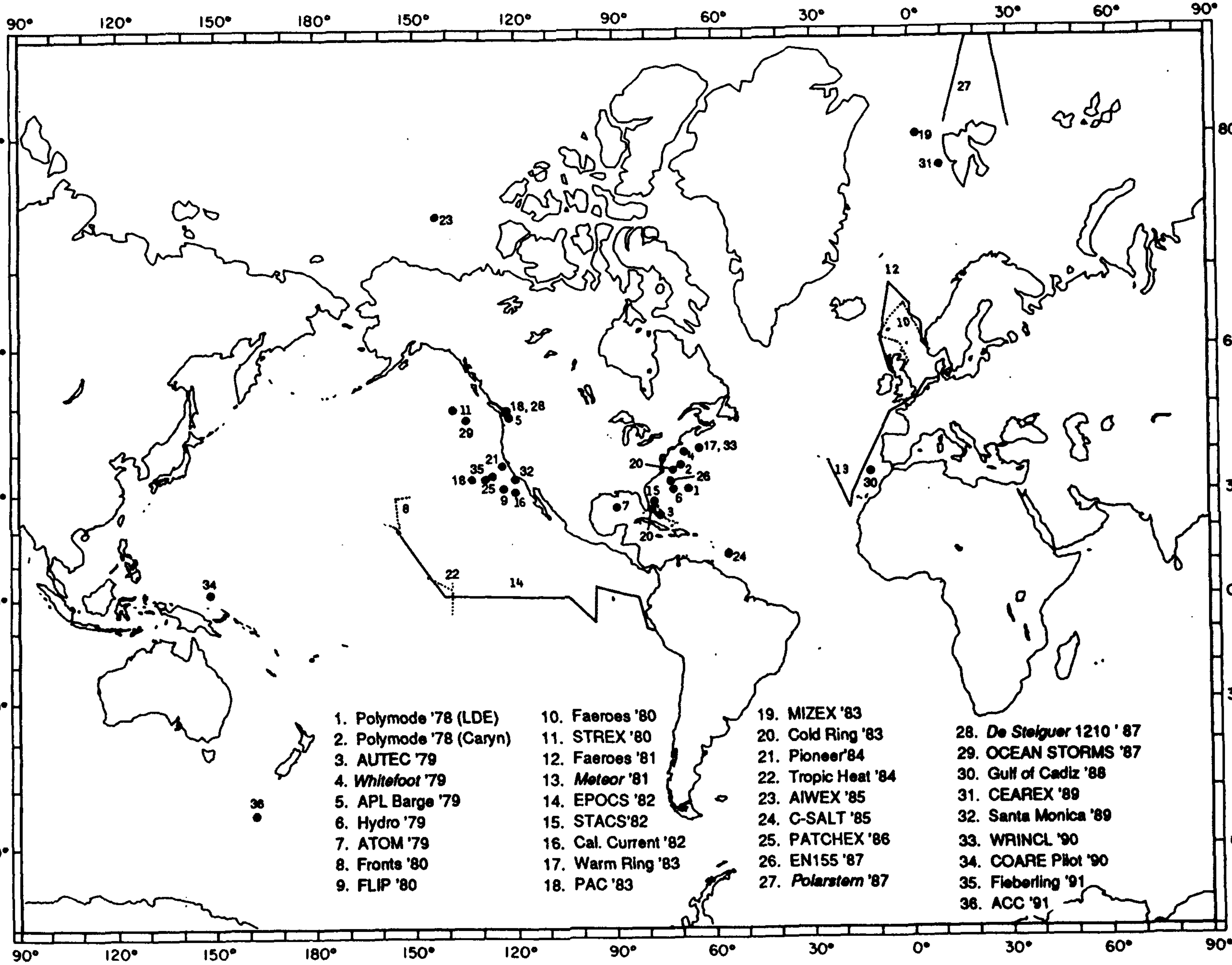


Figure 1. Locations where UW investigators have deployed XCPs.

Scientific development and operation of the XCP were summarized in 1982 in a report entitled "Design, Operation and Performance of an Expendable Temperature and Velocity Profiler (XTVP)" (Sanford et al., 1982). Since then, the XCP has undergone a number of changes: a radio link rather than a wire link is now used to transmit data from the surface unit to the receiving unit; the depth capability has been increased from 850 to 1500 m; air-launched units (AXCPs) have been developed by packaging XCPs in sonobuoy containers; a new type of AXCP, the slowfall, has been developed to enhance observations of surface wave oscillations in the upper 200 m of the water column; and XCP processing methods have become more sophisticated. In addition, some XCP users have experienced difficulties in acquiring and processing their data and would have benefited from a description of our approach. Thus, we felt it was time to compile our recent experiences and findings into a single volume.

1.2 Theory of Operation

The XCP provides a vertical profile of the relative horizontal velocity and temperature. Velocity determinations are based on the principles of electromagnetic induction that govern the weak electric currents induced by the motion of electrically conducting layers of seawater through the Earth's magnetic field (Sanford, 1971). The magnitude of the electric current is related to the velocity of the conductor, its conductivity, and the strength of the magnetic field. The XCP determines this current by measuring the voltage between horizontally spaced electrodes falling through the water column. An extensive discussion of the theory of operation is provided by Sanford et al. (1982).

2. INSTRUMENTATION

2.1 Probe Description

2.1.1 XCPs

A short description of the XCP is given here; more detailed information can be found in the report by Sanford et al. (1982).

The standard XCP is designed to be launched from a vessel that is under way. The entire system—consisting of a surface float with a radio transmitter, a free-falling sensor probe, and wire connecting the two—is simply tossed overboard (Figure 2); there is no mechanical tether between the vessel and the sensor. The total package weighs about 10 kg and is 12 cm in diameter by 100 cm long. The probe is projectile-shaped, with a cruciform tail and ring shroud; it contains electrodes, a compass coil, electronics, batteries, a thermistor, and wire-spooling components similar to those used in expendable bathythermographs (XBTs). The probe weighs 900 g in seawater and is approximately 5 cm in diameter by 42 cm long. The mechanical designs of the various XCPs (XCP, AXCP, and slowfall AXCP) are shown in Figure 3.

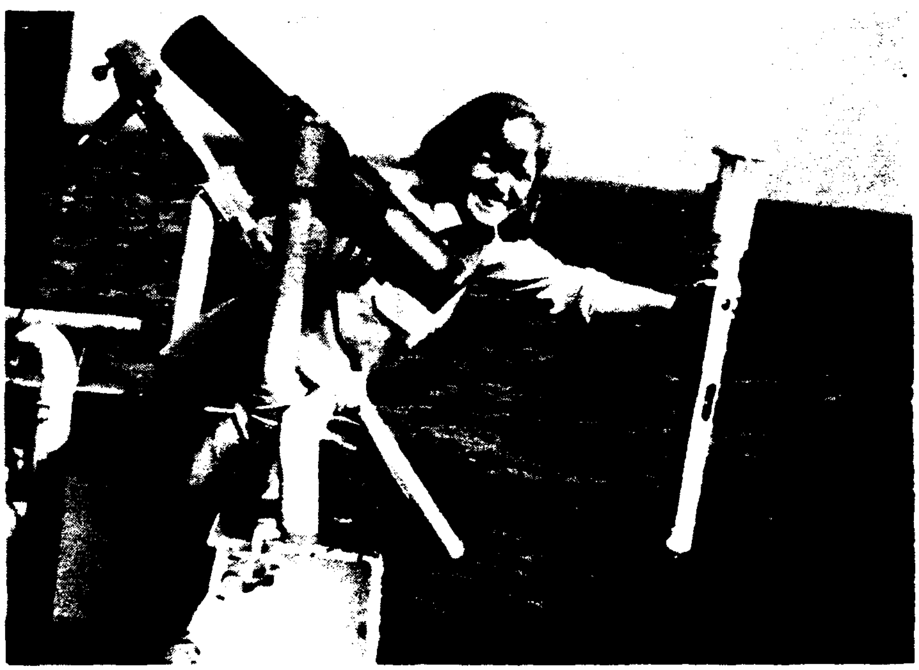


Figure 2. XCP launch from stern of an underway vessel.

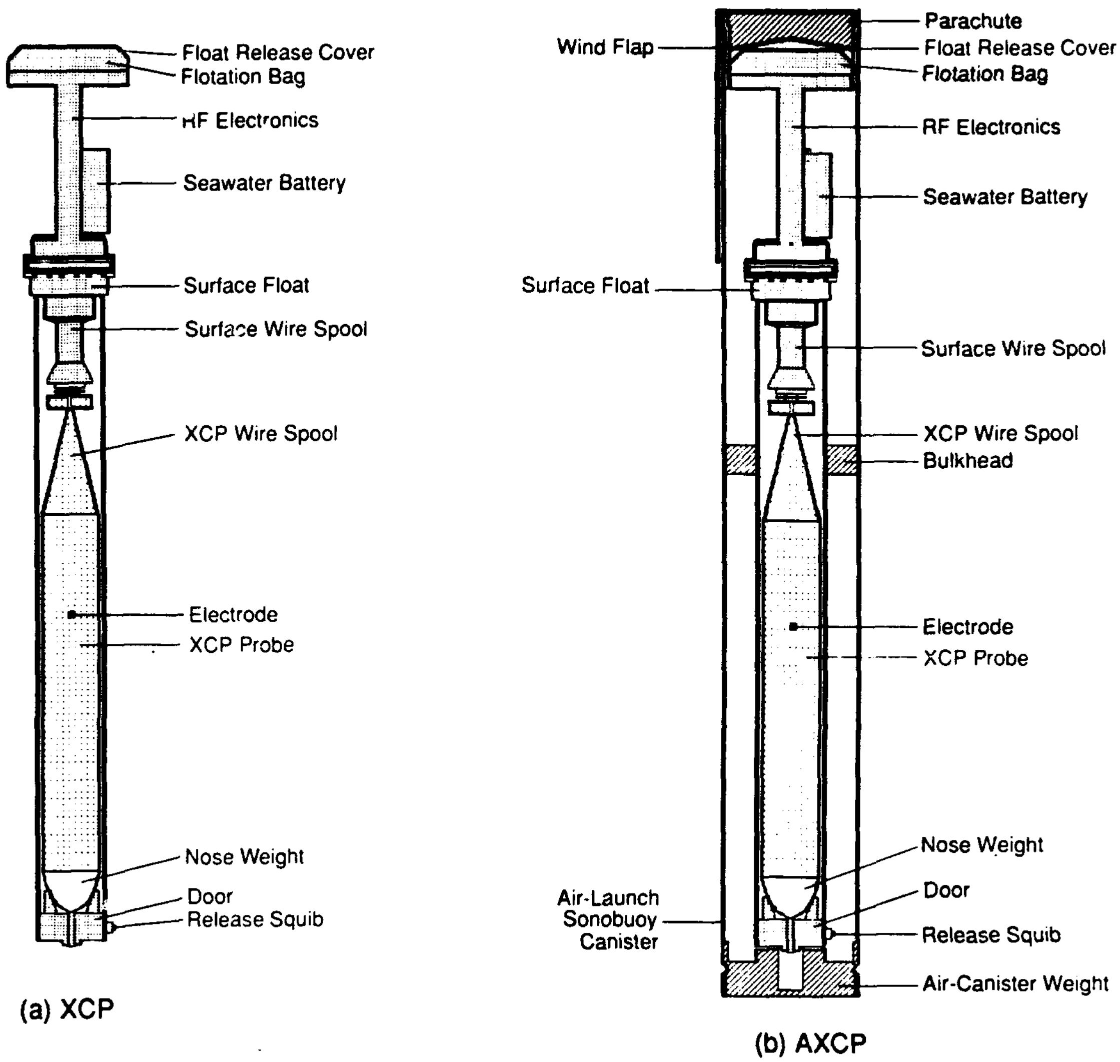
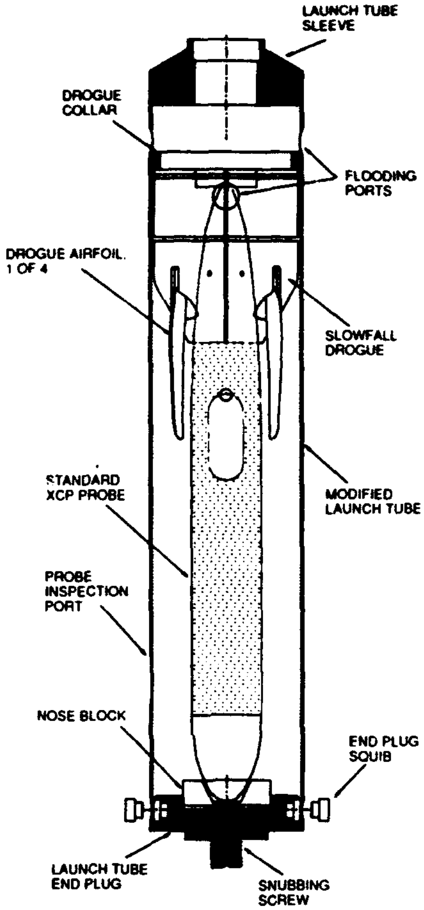


Figure 3. XCP schematics. (a) XCP, (b) AXCP, (c) slowfall AXCP (next page).



(c) Slowfall AXCP

Figure 3, cont.

The probe contains two silver-silver chloride electrodes separated by 5 cm. A measured voltage of 50 nV across the electrodes equates to 1 cm s^{-1} of relative motion at midlatitudes. Determination of the two horizontal components of velocity is enabled by a compass coil wound coaxially over the electrode tubes. The XCP probe spins 16 times per second during descent. As the probe falls, the compass-coil signal is used to determine the location of magnetic north once per revolution. A thermistor mounted within a flow tube on the probe provides a continuous vertical temperature profile.

The motionally induced voltage, sensed between the silver-silver chloride electrodes, and the compass coil voltage are amplified separately and processed through voltage-to-frequency (V/F) converters. A third frequency is determined based on the resistance of the thermistor. Frequency-modulated (FM) signals are summed together for transmission up the wire connecting the probe to the surface float and telemetered to the

ship via a radio frequency (RF) transmitter to a VHF radio receiver on the launching vessel. The output of the RF receiver is amplified, demodulated, and digitized by the signal processor for direct computer storage.

Deployment consists of the following series of events, which occur within 50 s of impact with the water's surface (see diagram in Figure 4). The XCP package, being negatively buoyant, sinks, flooding the interior and the seawater-activated battery contained therein. The battery provides power to fire a squib which punctures a CO_2 cartridge. The CO_2 inflates a flotation bladder, and the system, buoyed up by the bladder, floats to the surface. About 40 s later, a timer, activated at battery power-up, fires a second squib, which uncaps the bottom of the probe's launch tube. The probe then falls at about 4.5 m s^{-1}, rotating at about 16 Hz as it descends. As it drops through the water column, it trails fine, two-conductor XBT wire which deploys from spools on both the probe and surface float. This method of deployment eliminates an increasing drag force and allows the probe to maintain a uniform descent speed. The wire has a breaking strength of about 1 lb.

The probes currently manufactured by Sippican, Inc., are denoted as Mod 7s. The Mod 6 XCPs produced by Sippican used a wire link to transmit data from the probe all the way to the receiving equipment on the ship and provided data to only 850 m depth.

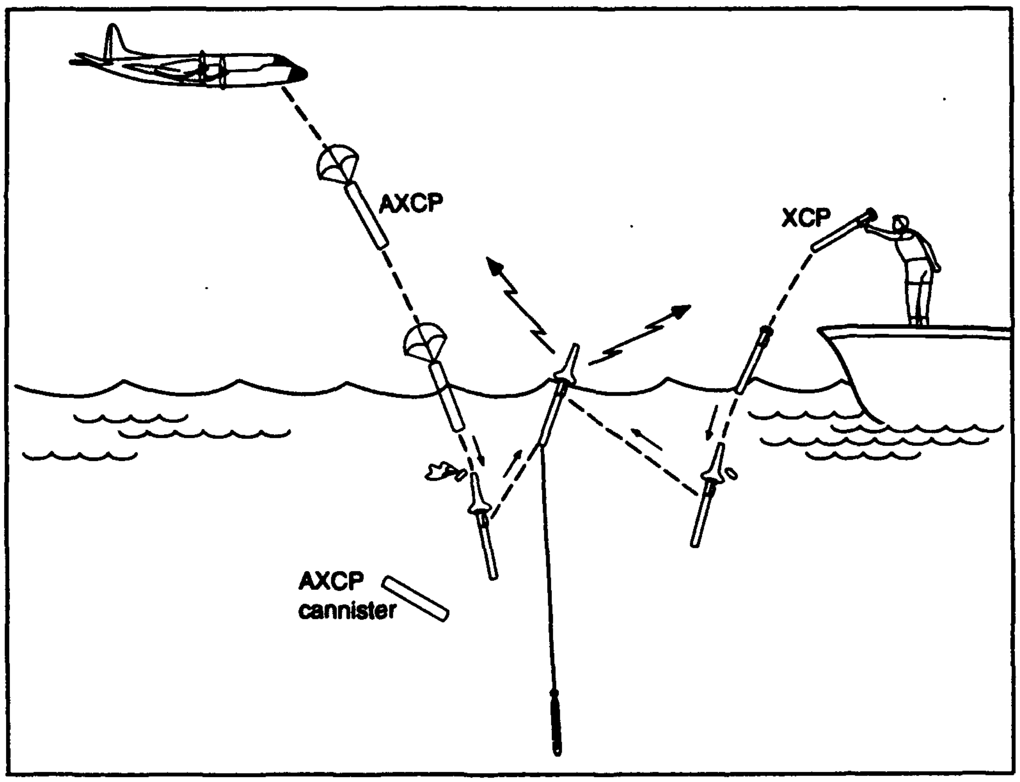


Figure 4. XCP launch sequence from underway vessel and aircraft.

Sippican routinely manufactures probes that transmit on one of three sonobuoy RF channels: 12, 14, and 16. Table 1 lists the sonobuoy channels and their corresponding frequencies. With advance notice, Sippican can manufacture probes that utilize sonobuoy channel 10. However, a channel-10 radio must be installed in a MK-10 digital data interface to be able to receive channel-10 data. In a two or three channel MK-10, one of the existing radios can simply be exchanged for a channel-10 radio, and no other modification is needed.

Table 1. Sonobuoy channels and corresponding radio frequencies.

Sonobuoy Channel	Radio Frequency
Channel 10	169.0 MHz
Channel 12	170.5 MHz
Channel 14	172.0 MHz
Channel 16	173.5 MHz

2.1.2 AXCPs

The AXCP (Figure 3b) is an air-launched version of the XCP. It consists of the XCP described in the previous section with the addition of a parachute decelerating system and an outer aluminum tube. These modifications allow the system to be launched through normal sonobuoy launch tubes (either with a cartridge-activated device or gravity launched) while the radio receiver is on board the aircraft.

The entire unit is housed in a protective, A-size sonobuoy canister. Upon launch from an aircraft (Figure 4), a small wind flap deploys, pulling the parachute from the canister. The unit falls to the ocean surface at a rate of about 25 m s^{-1}. As with the XCP, a seawater battery is activated upon impact, turning on the telemetry radio, firing the CO_2 cartridge, and inflating the flotation bladder. The pressure from the inflated bladder pushes the weight off the upper end of the sonobuoy canister, allowing the float to separate from the canister and rise to the surface. The AXCP then performs identically to the XCP. According to Sippican, the AXCP can be launched at aircraft speeds up to 180 knots and at altitudes up to 2000 ft. We have launched it from 10,000 ft and at aircraft speeds greater than 200 knots (Osse et al., 1989; D'Asaro et al., 1990). Data are acquired and processed in the same manner as for XCPs.

2.1.3 Slowfall AXCPs

The slowfall AXCP (Figure 3c) was developed at APL-UW for the OCEAN STORMS program (Osse et al., 1988; D'Asaro et al., 1990). It is a modified version of the AXCP designed to improve launch stability and impact survival and to fall slowly (<1 m s^{-1}) through the upper 200 m of the ocean to observe more cycles of surface wave oscillations. The device was based on the standard AXCP described in Section 2.1.2 but incorporates a winged drogue to slow descent over the upper ocean while maintaining a sufficient rotation rate. At a preset depth, the drogue is jettisoned, and the probe reverts to its normal descent and spin rates. Figure 5 shows the unit's configuration during launch, descent, and jettison of the drogue.

Forty slowfall AXCPs were deployed in late 1987 as part of the OCEAN STORMS Program (D'Asaro et al., 1990). Nineteen units provided profile data.

Investigators have experimented with another type of slowfall AXCP obtained from Sippican, Inc., that had a smaller and lighter, square nose weight (designated the T-11 by Sippican). The lighter nose weight caused the AXCP to fall at about half speed (i.e., 2.2 m s^{-1}), enabling better filtering or observation of surface wave signals than with standard AXCPs.

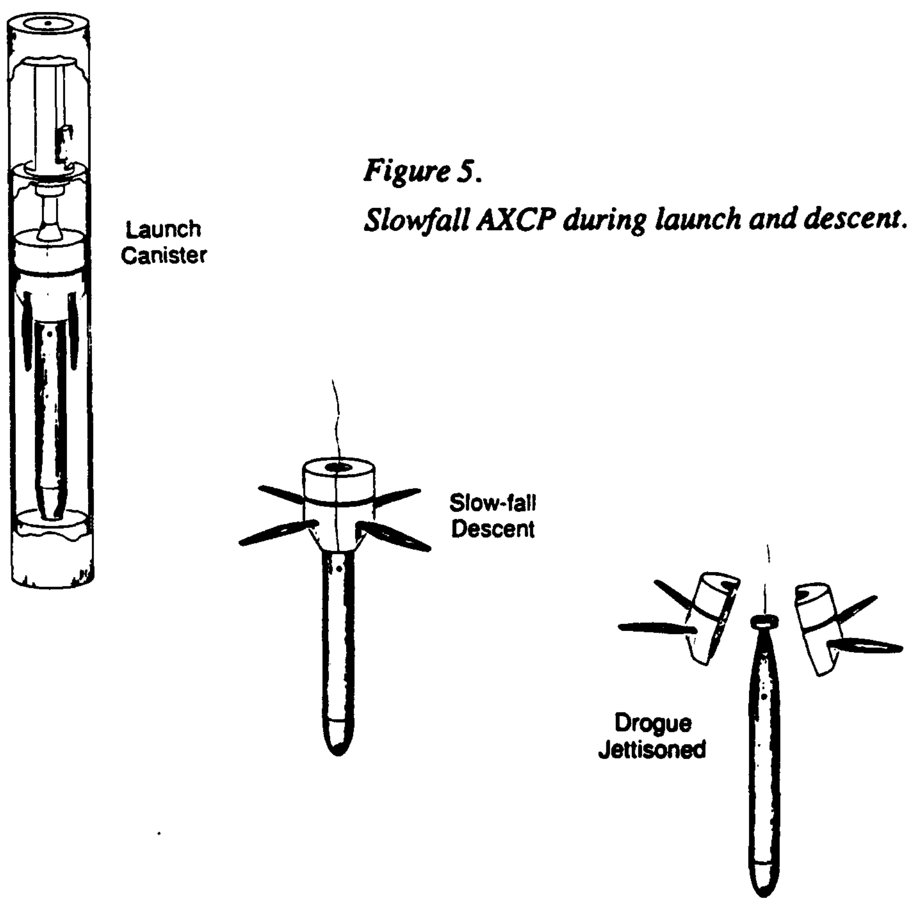


Figure 5.
Slowfall AXCP during launch and descent.

2.2 Data Acquisition Equipment

The basic requirements for XCP data acquisition are an antenna, a receiver or signal processor, and a data storage device (e.g., a cassette recorder or VCR). Additional equipment can include multiple antennas, computers, disk drives, printers, and plotters.

For an experiment with a large XCP component, we use a full complement of equipment, including multiple antennas at different locations on the ship, multiple receivers to acquire data simultaneously from two or more XCPs on different channels, and a computer equipped with floppy and hard disk drives for real-time processing and display. Such an installation is described in Section 2.2.1 as our standard system. We typically use an independent backup system (such as that described in Section 2.2.2) with its own radios and recorders in conjunction with the standard system.

For an experiment with only a few XCPs or occasional XCP deployments (such as in the Arctic), we use a portable system consisting of an antenna, a receiver, and a tape recorder. We recommend using digital audio tapes (DAT) or VHS tapes for data recording although audio cassette tapes are adequate. With the portable equipment, the data are played back from the magnetic tapes and transferred to computer for subsequent processing upon return to the laboratory. Although profiles of velocity cannot be displayed in real time with the portable gear, headphones can be used to listen to the FM signal of the probe as it falls. After listening to recordings of a few probes, one can differentiate between the signal of an XCP that is functioning properly and one that is not. This type of system is described in Section 2.2.3. Both the standard and portable systems have been used successfully by APL and other investigators. In addition, an easily configured homemade data acquisition system is described in Section 2.2.4.

For operations at sea or in the air, the acquisition equipment, particularly computers, must be shock resistant. We have had good success in the field with Hewlett-Packard (HP) equipment. Another important consideration for field operations is "clean" power. We always use Topaz, Inc., power conditioners at sea.

2.2.1 Standard Data Acquisition System

Equipment used in our standard system includes antennas, a receiver or signal processor, a computer with multiple data storage media, what we call a "patch panel" which includes backup sonobuoy RF receivers and signal strength meters, and a spectrum analyzer.

2.2.1.1 Antennas

Very high frequency (143–174 MHz) antennas are used for XCP reception. The electric polarization must be vertical to match that of the transmitting antenna on the probe. Some directionality helps to reduce fading due to multipath interference from reflections off the ship and to increase signal strength. Too much directionality is

counterproductive because vessel pitch, yaw, and small heading adjustments will cause signal dropouts. We have been most pleased with Cushcraft[1] Yagi antennas cut specifically for 170 MHz, and our recommendation is to use four-element Yagi antennas that have a beam width of about 66° and a front-to-back ratio of 18 dB. The front-to-back ratio is the ratio of the forward-looking gain of the antenna to the backward-looking gain. A four-element Yagi antenna mounted with the elements vertical 15 m or more above the water works very well at ship speeds of 6 m s^{-1} or less.

We have experienced good performance from directional log-periodic TV antennas as well as four-element Yagi antennas. We have not had good results with the simple omnidirectional ground-plane whip antennas that were initially supplied with the MK-10 digital data interface. Sippican, Inc., now offers the user a choice between an omnidirectional antenna and a Yagi antenna.

Television antennas are readily available and take no particular care in tuning. However, they have several disadvantages: They require a nonconducting mast; they produce more wind resistance than Yagi antennas and may not be strong enough for the winds encountered at sea; the standard mounting brackets assume horizontal polarization whereas XCP work requires the elements to be vertical. When using TV antennas, use coaxial cable and "baluns" (balanced-to-unbalanced transformers) to convert the 300 Ω antenna impedance to 50 or 72 Ω coaxial cable.

Because the Yagi antennas have a high front-to-back ratio, a steel or aluminum pipe can be used for support just behind the reflector element. Yagi antennas are easily mounted vertically to a vertical pipe. We keep the distance to any other conductor at 1 m or more, except for the supporting pipe, which is about 10 cm behind the reflector element of the Yagi. Yagi antennas tend to be more rugged, since no insulators are required between the elements and the boom.

Yagi antennas generally have a "gamma match" balun to convert the impedance of the feed line (coaxial cable) to that of the antenna. This balun must be adjusted to account for the minimum standing wave ratio (SWR) on the transmission line before use. This requires an SWR meter and the XCP radio test box described in Section 3.1.1. The gamma match can be adjusted before installation by mounting the antenna on a pipe similar to that to which it will be mounted on the ship; put the boom about 3 m off the ground and use a fairly short (about 5 m) feed line. Check the SWR at the lower end of the feed line after installation to ensure integrity of the feed line and antenna. If all is well, the SWR should be a bit less than when initially adjusted because the longer feed line absorbs more reflected energy.

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[1]Cushcraft/Signals, 48 Perimeter Road, P.O. Box 4680, Manchester, New Hampshire 03108; (603) 627-7877 or 1-800-258-3860

Further suggestions are (1) keep the antennas below the highest point of the ship to protect them from direct lightning strikes, and (2) use low-loss RG-8 coaxial cable. Smaller cables can cause significant losses in signal strength. We sometimes use an RF preamplifier and a signal splitter to increase the signal strength when operating multiple receivers from the same antenna.

2.2.1.2 RF Receivers

Any VHF radio capable of receiving 169–174 MHz, wideband, FM signals can be used for XCP data reception. The nominal frequency deviation of the XCP transmitter is 150 kHz peak to peak. A receiver with a bandwidth of 150 kHz will work for XCP data reception. After data are received they can be stored digitally, as with the APL-UW signal processor (Section 2.2.1.3.1) or the Sippican MK-10 digital data interface (Section 2.2.1.3.2), or stored in analog format on magnetic tapes such as those used in conjunction with the portable system (Section 2.2.3) or homemade data acquisition system (Section 2.2.4).

2.2.1.3 Signal Processors

2.2.1.3.1 APL-UW Signal Processor

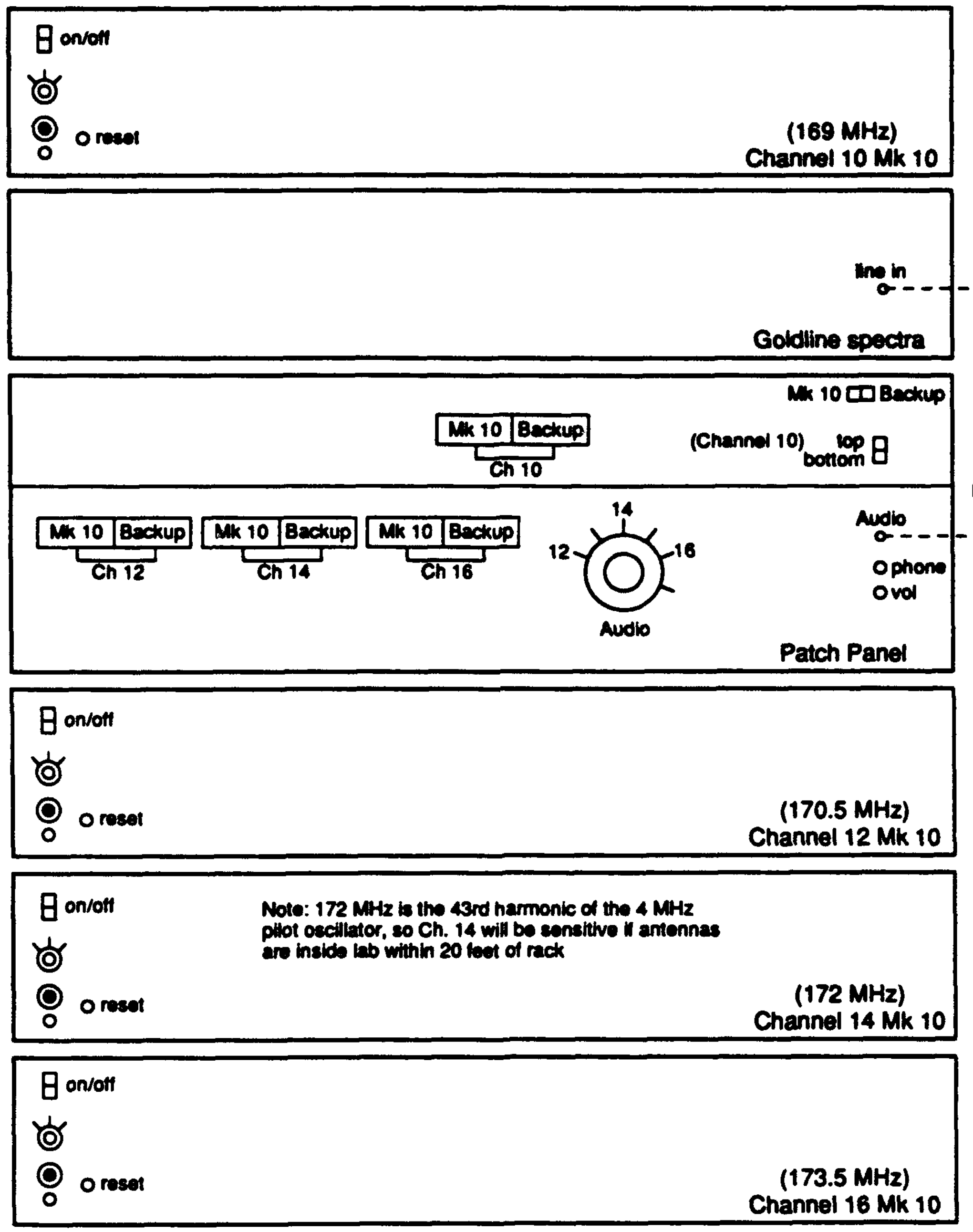
We initially used a digital signal processor built by Robert Drever of APL-UW for XCP operations. The APL-UW unit receives, amplifies, demodulates, and digitizes the incoming RF signal for direct computer storage. The design of this receiver is described in detail by Sanford et al. (1982). We last used the APL-UW receiver during *De Steiguer* Cruise 1210-87 (Carlson et al., 1987). We have since been using a receiver built by Sippican, the model MK-10 digital data interface, which we modify slightly. For some playbacks, we use the APL-UW processor with an HP-9845 computer.

2.2.1.3.2 MK-10 Digital Data Interface

The Sippican MK-10 digital data interface receives the RF transmissions from the XCP and converts the signal into digital format in real time. It then transfers the digitized XCP data over an IEEE-488 bus to a computer for further processing. The MK-10 is compatible with any computer that accepts the IEEE-488 output format. Up to three radio receivers can be fitted within the MK-10 case.

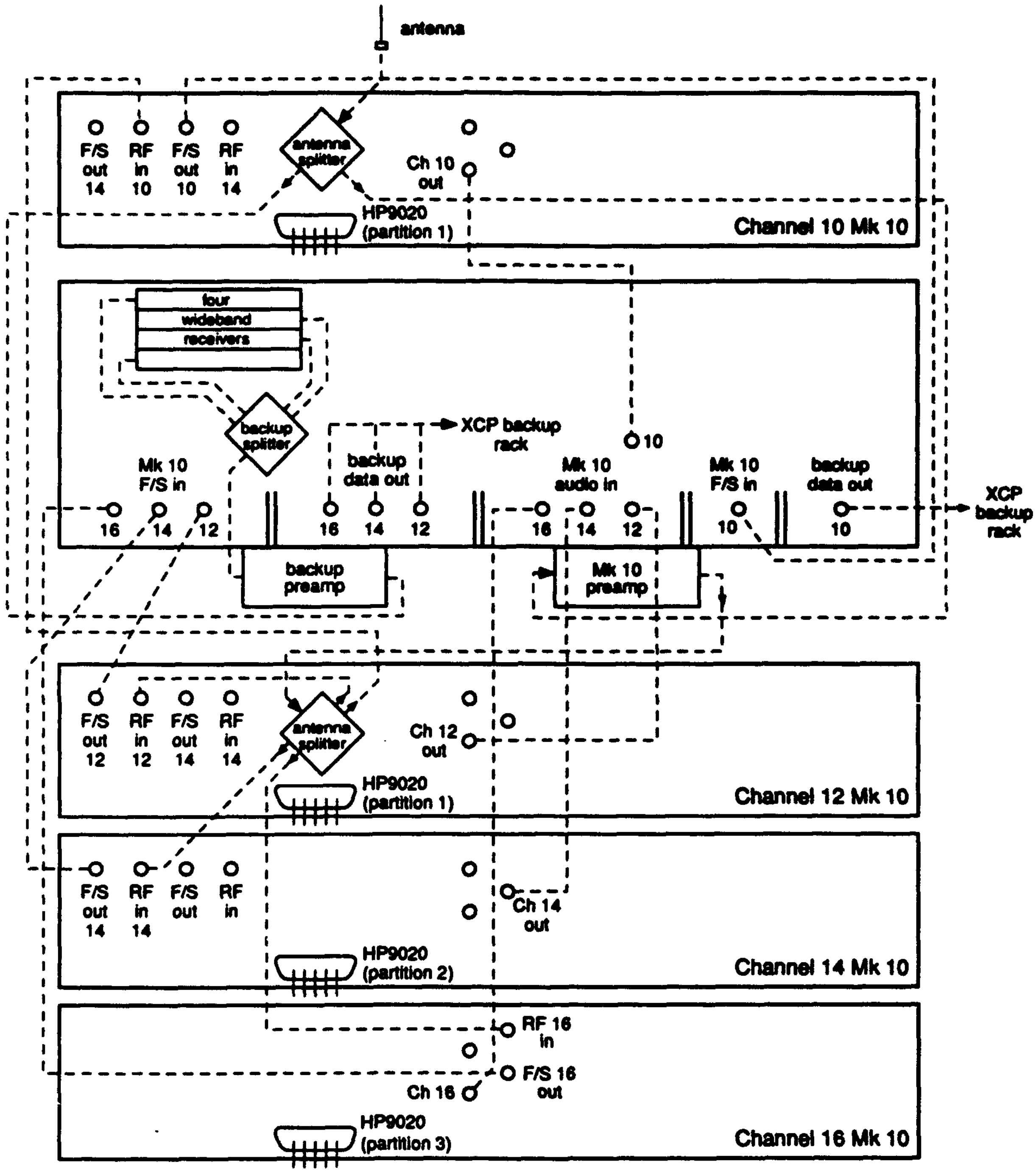
2.2.1.3.2.1 MK-10 Modifications

We have made several modifications to our MK-10s to improve their performance. Frequently, the MK-10 would hang up, and the only way to resume XCP operations would be to turn off the unit. A reset switch was therefore added to the left side of the MK-10 front panel (see Figure 6) so we could resume operations without having to turn



(a) Front View

Figure 6. Configuration of MK-10 rack used during Gulf of Cadiz Expedition. In this configuration, the channel-10 MK-10 and channel-12 MK-10 share partition 1.



(b) Back View

Figure 6, cont.

off the power. The switch momentarily sets pin 9 of the MK-10's 8031 microprocessor to +5 V. When the switch is depressed, the microprocessor and thus the MK-10 are reset as if the power had been turned off and on. The steps involved in this modification are

- Cut away part of the interlock panel to allow space on the left front panel for a pushbutton switch.
- Install a miniature pushbutton switch 1 in. to the right of the jack. (The switch is single pole, momentary, and normally open.)
- Using #26 twisted pair, brown wire, connect the switch to pins #4 and #1 (+5 V) on the motherboard backplane.
- On the component side of the A1 board, add a wire from U1 pin 9 to the pin 4 edge connector.

Occasionally in real-time operation, the signal processor would erroneously derive its time base from a spurious 8-kHz signal from the radio, corrupting the data. This is because an 8-kHz "pilot" tone is normally added to the recorded signal to compensate for tape wow. This tone is not needed when using DAT or PCM/VCR recording, which we recommend, and was inhibited for real-time data acquisition. This was done by putting a direct short across R21 on board A2, using one of the unused contacts on DIP switch 1 (see also Section 2.2.1.3.2.2).

The bandwidth of the MK-10 circuit is too wide, allowing noise to degrade detection of the zero crossing in the circuit. To reduce the bandwidth of the circuit, we replaced the C47 (470 pF) capacitor, which is located at the input of the zero-crossing detector on the A3 board of the MK-10, with a 0.47 μF polycarbonate capacitor. This changes the bandwidth of the circuit from 33.8 kHz to 338 Hz.

2.2.1.3.2.2 MK-10 Switch Settings

There are eight DIP switches on the A2 board of the MK-10. These switches permit the user to select which probe parameters are to be included in the "valid data" criteria. Four criteria are available: the existence of audio carriers for temperature (T), electric field (EF), and compass coil (CC), and modulation of the compass carrier by the rotation of the XCP at frequencies in the 10–20 Hz band (probe falling, PF). Opening a switch causes the corresponding parameter to be excluded from the valid data criteria. Far better choices on data quality can be made in software than in hardware. Therefore we recommend that the switches be set in the following positions for use with the HP-9020 acquisition program. Disabling all the criteria doesn't work.

	A2 Board DIP Switch	Field Setting
1.	Spare channel	open
2.	T flag	open
3.	EF flag	open
4.	CC flag	closed
5.	PF flag	closed
6.	NC	-
7.	NC	-
8.	Inhibit Pilot when closed	closed

The MK-10 decides whether it is listening to "real-time" or "playback" data by looking for energy at the frequency of the 8-kHz pilot tone put on the recorded data to compensate for tape wow. Because radio noise can insert a signal at this frequency, we disabled this feature (see Section 2.2.1.3.2.1). Closing DIP switch 8 on board A2 thus sets the MK-10 into the real-time mode. This switch should be closed during real-time operations.

2.2.1.4 Computers

Any computer that accepts the IEEE-488 output format fast enough can be used with the MK-10 digital data interface.

The computer used with the APL-UW receiver is an HP-9845 with an HP-9885M flexible disk drive and an HP-9872A XY plotter.

2.2.1.4.1 Computer Requirements

The computer requirements for acquiring and displaying XCP data are as follows:

HPIB Interface—A separate IEEE-488 (HPIB) interface is required for each MK-10, since the bus address is always 22. The number of MK-10s that can be used with a given system may often be limited by the number of available I/O slots in the machine.

I/O Rate —The MK-10 generates a packet of 17 bytes once per revolution of the XCP, typically every 60–70 ms; extra packets due to radio noise can decrease the average interval to perhaps 40 ms, with a few cycles separated by as little as 5 ms. Thus the total data rate is generally less than 425 bytes/s.

Servicing Interval–The MK-10 has an internal buffer which can hold only 128 bytes and thus needs to be emptied about every 300 ms. This requirement is often hard to meet with a multiuser, nonreal-time operating system.

Storage for Raw Data—Each XCP drop lasts about 350 s and thus contains about 145 kbytes of raw MK-10 data. We typically run the MK-10 continuously and save all the data. This produces about 1.5 Mbytes of raw data per hour for each channel. Three hours of data gathering with three XCP channels thus produces about 14 Mbytes of data.

This is too much to store on floppy disks, but is easily handled by hard disks or cartridge tape drives.

Storage for Processed Data—Typically, processed data are computed on an approximately 3-m grid, with each grid point consisting of about 10 scientific and engineering variables. A processed profile thus consists of about 50,000 words of data.

Processing Power—Processing an XCP profile at full resolution requires roughly 3 million floating point operations. If this is to be done in real time, a processing rate of about 10^4 floating point operations per second (10 kflops) is required for each channel processed. Processing the data at less resolution can reduce this requirement substantially; we have, for example, run a nearly real-time XCP acquisition program on an HP-9845 with a speed of 3 kflops.

Data Display—We display eight variables for processed XCP data: temperature, east and north velocity, velocity error, and four diagnostic variables. With multiple XCP profiles, this can rapidly fill up a graphics display screen. We found a color monitor to be nearly essential. A large color monitor with several screens or windows would be very helpful.

2.2.1.4.2 Data Acquisition

For XCP data acquisition during the OCEAN STORMS project, Eric D'Asaro (D'Asaro et al., 1990) developed software in HP-Basic for the HP-9020 that allows simultaneous real-time processing and display of data from up to three XCPs on different channels. The design is described in detail by D'Asaro et al. (1990). For the Gulf of Cadiz Expedition in 1988, the system was augmented by Eric Kunze to enable simultaneous acquisition of XCP, XBT, and XSV data. Only the XCP part of the acquisition system will be discussed here. The XBT and XSV portions are described in detail by Kennelly et al. (1989a). As the data are acquired, the complete raw data stream is saved on an HP-9144 magnetic cartridge tape drive connected to the HP-9020. Raw data from the XCPs are stored along with a time stamp, an indication of the probe's type, and the program partition that acquired the data. Preliminary processed XCP data can also be stored on floppy disk.

2.2.1.4.3 Equipment Used During the Gulf of Cadiz Expedition

A schematic of the acquisition system used during the Gulf of Cadiz Expedition is shown in Figure 7. A detailed view of the MK-10 rack is shown in Figures 6a (front) and 6b (back). Instrument settings are listed in Appendix B. We used four MK-10 digital data interfaces, one each of the four channels (10, 12, 14, and 16). In addition, a Goldline Digital RTA spectrum analyzer (model 30) displayed the frequencies of the probe during prelaunch testing and descent. The patch panel contained backup radios and meters. Since only three I/O ports were available on the computer, only three MK-10s

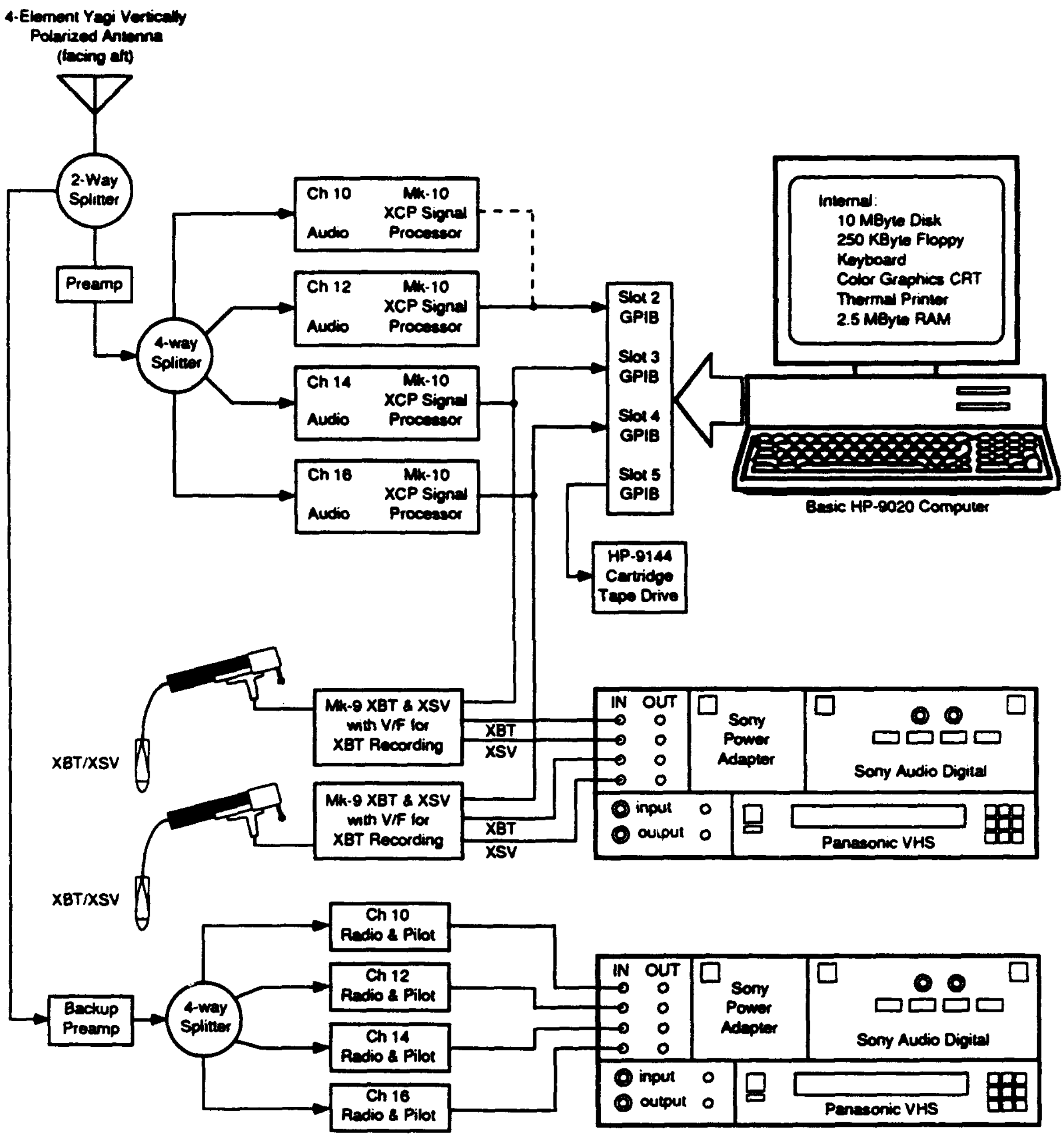


Figure 7. Configuration of XCP/XBT/XSV acquisition system used during the Gulf of Cadiz Expedition.

could be connected (via GPIB cables) at one time. Therefore, the channel-10 and the channel-12 MK-10s were alternately attached to partition 1. The channel-14 MK-10 was always attached to partition 2, and the channel-16 MK-10 to partition 3.

2.2.2 Backup Data Acquisition System

A backup system is used to store the audio signal on VHS audio/video magnetic tape. It consists of independent radios for the channels of XCPs to be received, a VCR, a Sony model PCM-F1 digital audio processor (PCM stands for pulse code modulation), and a power adaptor. Figure 8 shows the front panel of the XCP backup rack. The backup radios are located in the patch panel (Figure 6). During the Cadiz Expedition, the FM data from XCP channels 14 and 16 were stored directly on the audio tracks of the VHS tape. XCP data from channels 10 and 12 passed through the digital audio processor and were then recorded on the video tracks.

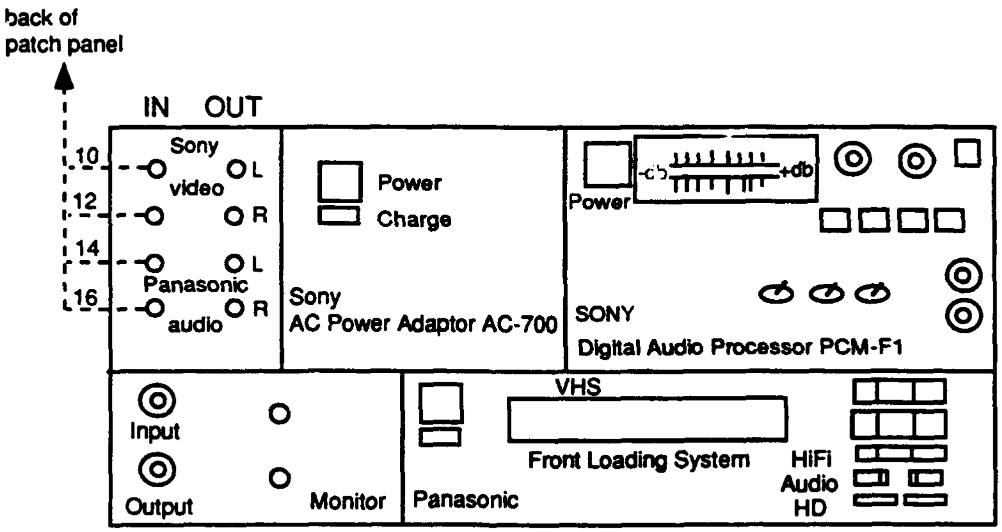


Figure 8. XCP backup rack (front view), consisting of a Panasonic VCR, a Sony model PCM-F1 digital audio processor, and a power adaptor.

2.2.2.1 Backup Media

A variety of media can be used to record backup XCP data, such as audio cassette tapes, video cassette tapes, and digital audio tapes.

2.2.2.1.1 Audio Cassette Tapes

Audio cassettes should be high quality, type II. Be sure the tape heads on the cassette recorder are clean prior to any recording. Each XCP takes 15 minutes or less of recording time. Be certain to log the tape counts to identify the XCPs later. A minimum number of XCPs should be recorded on one cassette. Operational procedures must be followed to avoid overwriting data. We recommend that only one side of each cassette be used. Be sure to write protect the cassettes immediately. The cost of cassette tapes is minimal compared with the price of the XCP.

2.2.2.1.2 Video Cassette Tapes

Video cassettes should be broadcast quality. As with audio cassettes, be sure the tape heads are clean prior to recording and be certain to log the tape counts so the XCPs can be identified later.

2.2.2.1.3 Digital Audio Tapes

Digital Audio Tapes (DAT) are a newer media and provide high quality recording.

2.2.3 Portable Data Acquisition System

Our portable system includes an antenna, a portable receiver, a tape recorder, and headphones. The portable receiver was designed and built at APL for channel 14 XCPs (172.0 MHz, wide band, FM). The audio signals received from the XCP are then mixed with an 8-kHz "pilot" tone to provide a time base. A tape recorder connected to the "receiver-mixer" jack is used to record the output for later reprocessing. Use of DAT obviates the need for a pilot tone and gives a better recording. However, DAT may not work well in cold field conditions. Upon return to the laboratory, the data are played back using a MK-10 and computer for processing and display.

2.2.4 Homemade Data Acquisition System

A simple XCP receiving system can be made using a good tape recorder and any radio capable of receiving 169–174 MHz, wideband FM signals. We suggest a four-element Yagi (or TV) antenna, a Yaesu FRG 9600 radio receiver, and a DAT recorder. Analog tape recorders will cause some signal degradation due to tape wow. The DATs are later replayed into a MK-10 digital data interface.

3. EQUIPMENT TESTS

3.1 Playback of Standard XCP Cassette

Once launched, an XCP cannot be retrieved. It is therefore well worth the effort to ensure that the receiving equipment is working properly. Prior to any XCP deployments, a complete simulation of an XCP drop should be done by playing a tape of a previously launched XCP through a radio transmitter. The items necessary to test the receiving equipment are

- a whip antenna
- a radio transmitter test box that simulates an XCP drop
- a portable tape player
- a cassette with a previously recorded (i.e., standard) XCP drop on it
- a paper graph of temperature and velocity components corresponding to the data on the cassette tape for comparison with the output of the current test.

We have found that the single most valuable piece of equipment for XCP work from any platform is the radio transmitter test box. This box is easily constructed using radio transmitters from XCPs. Figure 9a shows a typical test box and the pinouts. Section 3.1.1 describes how to construct one.

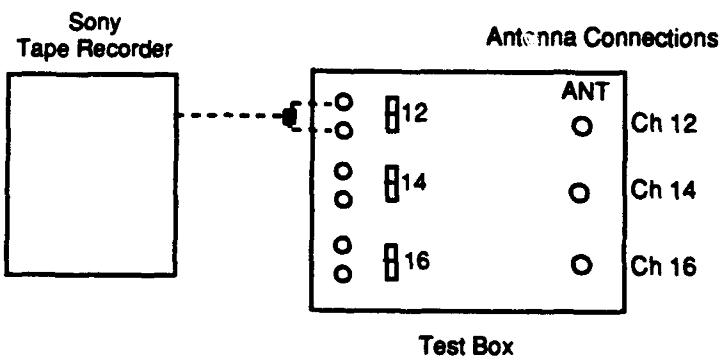


Figure 9a. XCP test box containing radio transmitters for channels 12, 14, and 16. The test box is powered by batteries and uses a tape recorder to generate the XCP audio signal.

3.1.1 Radio Transmitter Test Box Construction

The radio transmitter test box is constructed using one or more radio transmitters taken from XCPs. Figure 9b shows how to wire the radio transmitter board once it has been removed from the XCP. One or more such transmitters are mounted inside a metal box, each with a connector for an external antenna. An important part of this system is a foolproof "off" switch, or several redundant switches, so that the transmitter does not activate inadvertently during data acquisition and overpower the real XCP signals. We have used a test box with up to three radio channels (Figure 9a) so that the transmissions of up to three XCPs could be simulated.

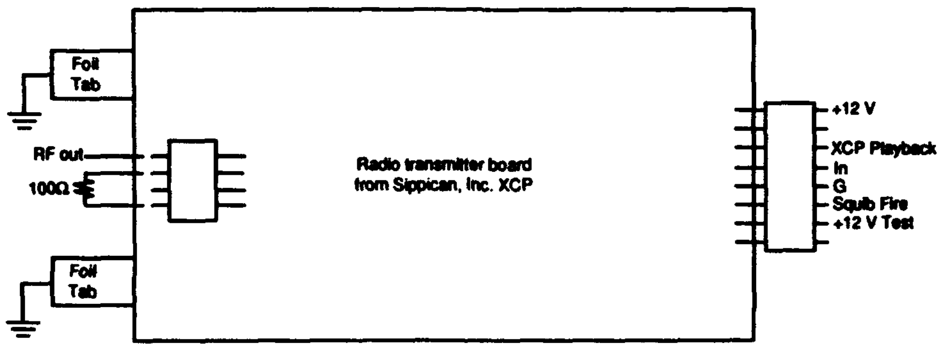


Figure 9b. Pinouts for RF transmitter board on XCP.

3.1.2 Radio Transmitter Test Procedure

To perform this test, carry out the following steps:

- Start the acquisition program on the computer. Make sure the proper recording media are loaded (e.g., floppy diskette and cartridge tape).
- Start recording on the backup system (VCR).
- Take the radio transmitter test box outside the laboratory to the ship's deck.
- Select the radio channel you want to test and connect the whip antenna and tape recorder to the test box (Figure 9a).
- Turn on the power.
- Press the play button on the cassette tape player. Play an entire drop on the selected channel.
- Listen to the tape player to make sure a drop is being played.

- Repeat this procedure for each channel.
- Turn off the test box. Make sure the test box power is off so that test box transmissions do not interfere with actual XCP drops.
- Now check that the transmission was acquired by the receiving equipment/computer system inside the laboratory. With the APL system, profiles should have been generated on the computer screen as the cassette was played for each channel.
- Pause the acquisition program. The profiles can then be plotted for comparison with the graph of the standard XCP.
- Check that the standard XCP data were written to disk properly by processing the files.
- Rewind the VCR and process all channels to ensure that data were recorded properly on the backup system.
- After verification, test data can be deleted from the storage media.

3.2 Portable Receiver Test

If the portable system is to be used for XCP data acquisition rather than the standard system, the portable receiver should be tested prior to field operation using the following procedure.

- Check the voltages on the portable receiver test points. Change the batteries if the voltage is less than 12.0 V after a few minutes of running.
- Turn on the portable receiver and plug headphones in the "receiver-mixer" jack. You should hear a (LOUD) hissing of radio noise and an 8-kHz tone. If you don't hear anything, the receiver is broken. If you hear a tone, but no hissing, either something is broken or there is radio interference on this channel. The noise should change when you attach the antenna.
- If the receiver is broken, try opening it up, checking the wires, and/or replacing either the board or the power-supply chip.

3.3 Probe Tests

There are three tests that can be performed on an XCP to determine if it is operable before it is deployed:

- a radio frequency (RF) test
- an audio frequency (AF) test
- a compass coil (CC) test.

XCPs that fail any of these tests should not be deployed. All suspect units should be double checked. In addition, a visual inspection should be made of the agar surrounding the electrodes.

An XCP launch checklist is provided in Appendix C that outlines the steps described here. When many probes will be dropped in rapid succession, we perform the checkout steps on a group of probes all at once. Otherwise, we typically check an individual probe shortly before launch, having already checked out a backup probe or leaving sufficient time to be able to test another if the probe is a dud. For shipboard operations, one laboratory bench is left free to be used as a checkout station. (Note: These tests will not detect all bad probes, since they do not test the XCP's batteries or the battery switch.)

Items necessary for the probe tests include

- a dual 12 V power supply or a pair of 12 V lantern batteries
- test cable
- a magnet.

The power supply for the RF and AF tests is diagrammed in Figure 10. A test cable can be made by simply mounting three pins in a plastic block at the spacing of the test points (0.25 in.) on the XCP. The test point contacts are 3/32 in. in diameter. A test cable can also be obtained from Sippican, Inc. (Note: Sippican uses the terminology "XCP test harness.") The test cable enables power to be easily applied to all three test points at one time.

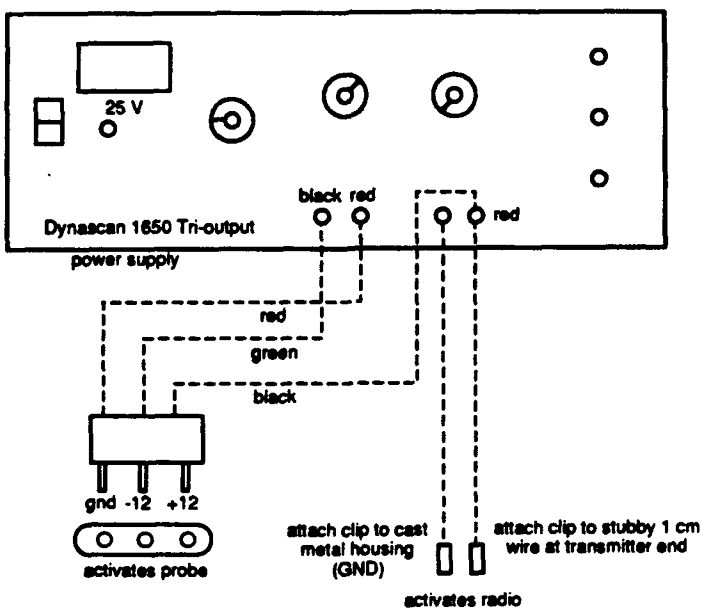


Figure 10. Power supply used for XCP probe tests. Diagram shows the wiring for activating the radio (RF test) and powering the probe (AF test).

To prepare the XCP for testing, remove it from the shipping box, and place the XCP, still in its inner cardboard form, on a laboratory bench. Slit the tapes on the inner cardboard form to expose the XCP. Leaving the XCP in the form makes it easier to test on a moving ship. (When the tests are completed, the form can be closed and retaped, and the XCP put back in its shipping box until launch.)

Enter the following header information on the launch checklist (Appendix C):

- probe serial number
- Mod
- channel number
- initials of person performing checkout
- expiration date of probe
- date and time of checkout.

The drop number can be entered at this time if it is known or it can be entered later when the probe is actually deployed.

3.3.1 Radio Frequency Test

Turn on the power to the MK-10 or other radio receiver. Turn the channel selector on the MK-10 to match the channel of the XCP being tested. Plug headphones into the MK-10. (We use a patch panel that enables us to hook together multiple MK-10s and select the channel we want to listen to.) Listen using the headphones. You should hear white noise.

There are two wires without insulation near the transmitter end of the XCP (Figures 11a and 11b). One wire is much longer than the other; this is the squib wire and should not have power applied to it. Also, it should not touch the XCP case. Check off on the launch checklist that the squib wire is free. The other wire is about 1 cm long. Using a 12 V power supply (Figure 10) or a pair of 12 V batteries, connect +12 V to the shorter wire on the side of the XCP and ground the power to the cast metal XCP housing above the wire (Figure 11a).

CAUTION: Be careful when powering up an XCP. Connecting power to the wrong wire will cause the air bag to inflate.

Turn on the power supply. This powers the transmitter only and does not activate the timer or air bag. Listen with the headphones. The noise you heard previously should be gone. We call this "quieting." If you heard quieting, note that on the checklist.

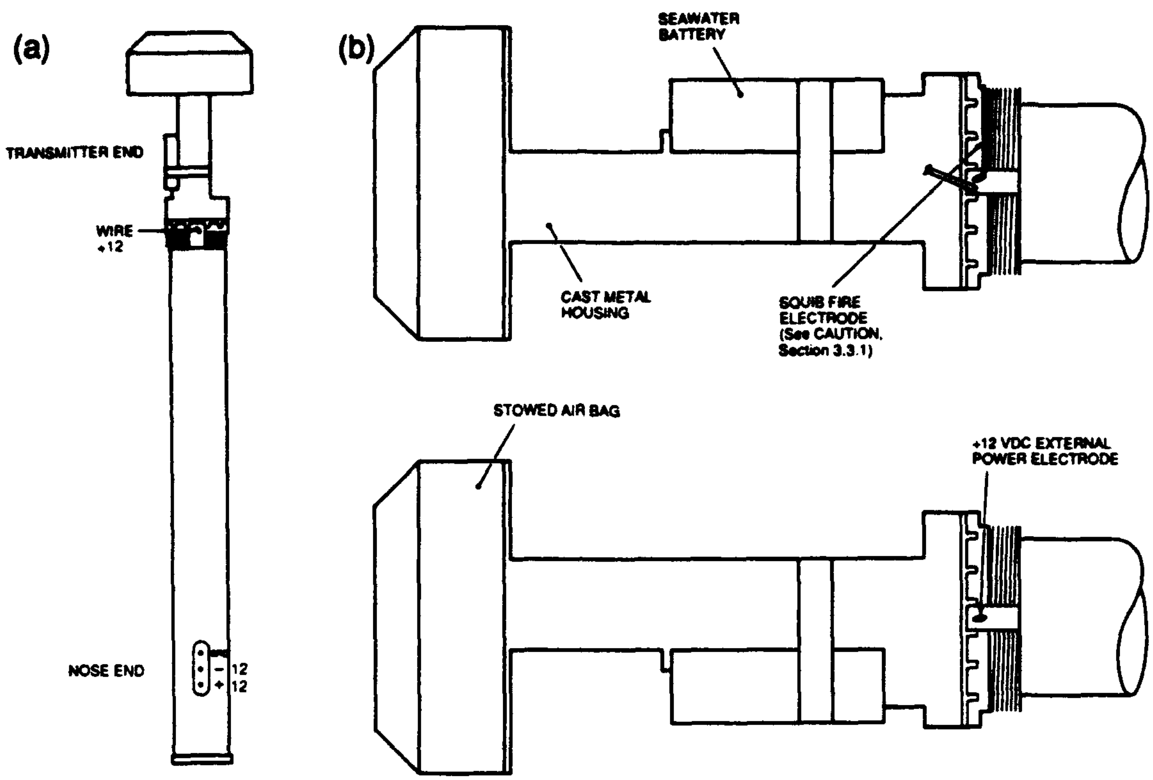


Figure 11. XCP power-up diagram. (a) Schematic showing test points at nose end. (b) Enlarged view of transmitter end of XCP showing squib wire, wire for +12 V connection, and cast metal housing.

3.3.2 Audio Frequency Test

A 3/4 in. by 1/2 in. hole in the plastic cylinder exposes the three test points near the nose of the XCP (Figure 11a). Connect the three-pronged XCP test cable to the power supply. Be careful with the test cable (it carries 24 V) and its orientation. Apply power to the test points on the XCP as follows:

- nearest to nose +12 V
- next (middle point) −12 V
- nearest tail ground

This procedure will power the probe electronics. To verify that the probe is functioning, it is necessary to be powering the transmitter at the same time (as discussed in the previous section) and to run a signal to the antenna and through the receiver. Listen on headphones for XCP tones. If you are also using a spectrum analyzer, you should see three high energy peaks:

- at 0.35 kHz for temperature
- at 1.2 kHz for electric field
- at 2.4 kHz for compass coil.

On the launch checklist, note if the XCP tones were heard and if the peaks were seen on the spectrum analyzer.

3.3.3 Compass Coil Test

The compass coil is used to determine the direction to magnetic north and is thus sensitive to a magnet. While both the transmitter and probe are still powered up, wave a magnet over the XCP electrodes. Listen for a warbling sound from the compass coil signal. If heard, note on checklist.

If the probe failed any of the tests, repeat them. If it still fails, do not launch it. Disconnect the power from the XCP.

3.3.4 Visual Examination of Agar

If the agar in the electrode chambers is dried out, a poor quality profile may result. Therefore a visual check should be made of the condition of the agar.

- Remove the two pieces of tape over the XCP electrodes.
- Remove the clear plastic that keeps the tape from touching the agar.
- Check the condition of the agar surrounding the electrodes. It should be moist and completely fill the electrode cups.
- Note the condition of the agar on the checklist.

If the agar appears dried out or has shrunk away from the walls of the cups, the safest recommendation is to return the probe to Sippican, Inc., for a credit. If supplies are readily available (Sippican can provide an agar replacement kit), new agar can be used to replace the dried out agar surrounding the electrodes. If best performance is not required, go ahead and drop the XCP.

If the XCP is to be launched immediately, complete the remainder of the launch checklist. Otherwise, replace the clear plastic and tape over the electrodes, close the cardboard form around the XCP, and return it to its box until time for deployment.

4. SIPPICAN PROBE CALIBRATIONS

The XCP contains a compass coil, wound coaxially about the electrode arm, which produces a signal at the probe's rotation frequency as the probe rotates within the Earth's magnetic field. The zero crossings of the compass coil signal are used to determine the probe's orientation relative to magnetic north. The phase shift between the CC and EF signals is then used to determine the orientation of the horizontal water velocity relative to magnetic north. The circuitry in the XCP and the MK-10 introduces gains and phase shifts in the EF and CC signals. These must be removed during processing so that the orientation of the water velocity relative to magnetic north can be accurately determined.

The following gains are used by the program *xcppro* during processing:

- compass voltage gain, G_{cca}
- correction voltage gain, G_{cora}
- electric field voltage gain, G_{efa}
- electric field deviation, G_{evfa}
- compass deviation, G_{cvfa}.

Sippican, Inc., calibrates each XCP individually to determine these gains. Alternatively, nominal gain values (values that apply equally to all probes) can be determined based on the circuit design and component tolerances or on measured values from a "typical" board. A question has recently been raised about which gain values should be used in XCP processing because there are significant consequences for probe performance and accuracy.

Our processing allows use of either individual values for each XCP or nominal values. We presently use gain values based on measurements on a board set (S/N 88132) provided by Sippican. Our values include the influences of the V/F converter and the MK-10. Section 6.3 lists the values we currently use in processing.

A review of Sippican calibrations for probes processed over the last couple of years shows a 10% jump in the gain values G_{cora}, G_{cca}, and G_{efa} in probe batches built after September 1988. Also, Sippican's calibration values are uniformly higher than the ones we determine with our calibration setup. As a consequence, the computed velocity profiles experience offsets (because of G_{cora} and G_{cca} errors) and have amplitudes that, in some instances, are off by more than 10% (because of G_{efa} errors).

The issue of which gain values to use is still unresolved. Further investigation is necessary.

Calibration reports are available from Sippican upon request. Requests should be made according to probe serial number.

5. DEPLOYING XCPs

5.1 Prelaunch Considerations

Before field operations commence, make sure sufficient data storage media (e.g. floppy diskettes and cartridge tapes) have been initialized.

Before deploying any XCPs, arrangements should be made with the bridge about the ship's speed during deployment. The ship should be at least two ship lengths away from the XCP when it falls to avoid electromagnetic interference from the ship's hull. For a 70-m-long ship, this requires a speed of 3.5 m s^{-1} (7 knots). We have launched XCPs at ship speeds up to 10 knots without loss of data. Speeds in excess of 10 knots may cause radio reception to weaken near the end of the profile if omnidirectional antennas are used. No problems have been observed with directional antennas.

During high-latitude deployments from the *Polarstern* in 1987, the delay in the XCP radio boards was extended from 40 s to 160 s to compensate for slower ship movement through ice, allowing ship speeds as low as 2.5 knots. The procedure to change the deployment delay of the XCP probe from approximately 40 s to 2.5 min. is as follows:

- Disassemble and remove the XCP transmitter board.
- On the component side of the board, carefully scrape/chip away the wax in the vicinity of pin 15 of IC U2. (Figure 12).

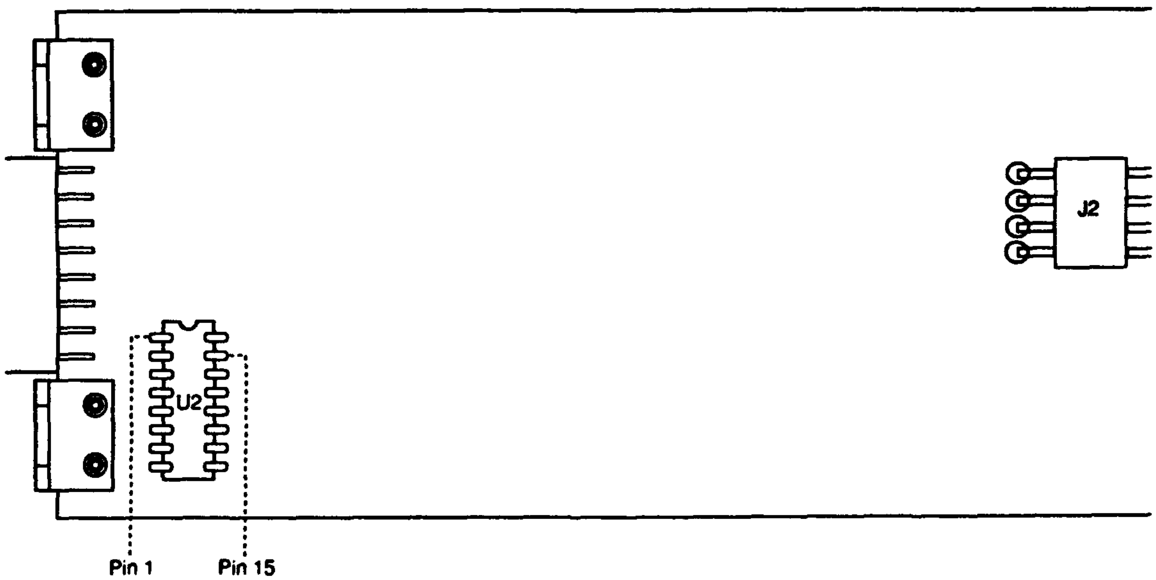


Figure 12. XCP transmitter board schematic. Note the location of IC U2. The locations of pins 1 and 15 are shown as viewed from top.

- When sufficient wax has been removed to access pin 15 of U2, carefully cut the pin 15 terminal on the IC using sharp bladed cutters. If necessary, separate the cut ends so they cannot make contact.
- On the underside of the board, scrape or chip away sufficient wax to access solder pads 1 and 15 of IC U2. Carefully solder a wire between pads 1 and 15. Ensure the wire lies close to the board to prevent snagging when reinstalling the board.
- Reinstall the transmitter board and reassemble the XCP.

5.2 Acquisition Equipment Preparations

To prepare the standard system for data acquisition, we execute the following steps:

- Restart the HP-9020 (turn off, then on).
- Load the data storage media: Insert an initialized cartridge tape into the HP-9144 tape drive, an initialized floppy diskette into the floppy disk drive, and a blank video cassette tape into the VCR.
- Load the acquisition program.
- Restart the MK-10s.
- Run the acquisition program.

With our acquisition program, we then need to make sure a partition is set up for the correct probe type, that the MK-10 is set to the appropriate sonobuoy channel for the probe that will be launched, and that communication has been established between the MK-10 and the HP-9020 computer.

At this time, complete the appropriate entries on the XCP log sheet (Appendix D):

- Enter the Drop#. We number our drops sequentially from the start of our XCP operations over a decade ago, and we start each new cruise on an even hundred; e.g., for Cadiz we launched probes 2401 through 2584, and the next XCP experiment started at drop 2600.
- Enter the Probe # (Sippican's serial number).
- Enter the RF channel of the probe.
- Enter the initials of the person completing the log and the date of deployment.
- Enter the floppy disk number, HP-9144 tape number, the VCR tape number, and VCR counter start value.

We now begin VCR recording. A drop checklist (Appendix E) is available for the computer operator to consult prior to launch.

5.3 XCP Preparations

Using an XCP that has passed the probe tests described in Section 3.3,

- Remove the two pieces of tape over the XCP electrodes.
- Make sure the clear plastic that keeps the tape from touching the agar is also removed.
- Remove the rubber band from the XCP transmitter end.
- Place the tapes and rubber band on the XCP launch checklist (see Appendix C, page C2) so that, in case of probe failure, there is proof that the tape and rubber band were really removed and are not the cause of the failure.
- If the drop number was not entered on the XCP launch checklist, do so at this time.

5.4 XCP Launch

The XCP is launched by hand over the side of a moving ship. No launcher is required. We have had the best results when the XCP is simply dropped over the quarter of a moving ship in an upright position, rather than heaved. For aircraft launch, an AXCP is deployed from a sonobuoy launch tube (see D'Asaro et al., 1990).

5.5 XCP Operational Sequence

When launched, the XCP, being negatively buoyant, sinks (Figure 4). A seawater battery within the surface buoy activates upon flooding and supplies power to the buoy electronics.

A squib-activated CO_2 cartridge inflates the flotation bladder which forces the unit back to the surface and supports an antenna. Power is also applied to the RF transmitter and to a timing circuit. The radio signal begins, and RF quieting should be heard on the radio. During daylight, one can see the XCP rise to the surface after deployment. If you don't see a floating XCP and don't hear any quieting, the XCP has probably sunk. The time of launch (i.e., the time when the RF turns on) should be entered on the XCP log sheet (Appendix D). Also at this time, enter the launch position and navigation method on the log sheet. Other environmental parameters (e.g., wind and wave conditions) can be entered on the log sheet's middle section.

The surface buoy releases the XCP probe 40 s after RF quieting, and the audio (AF) signal from the XCP begins. Enter the drop time (i.e., the time when the AF turns on) on the XCP log sheet. This can be detected by looking to see when the MK-10 lights go on (although they may be on already if there is a lot of radio noise) or listening for the XCP telemetry on the radio. On our system, we can check the meters on the patch panel (both

for the backup radio and the MK-10 radio). Check the record levels on the VCR (10 dB) and the PCM (20 dB). The probe descends at a rate of approximately 4.5 m s^{-1} and spins at approximately 16 Hz. The key signals from the XCP are shown in Table 2.

Table 2. Audio signals received from the XCP and their meanings.

Time	Event	Signal	Meaning
0	XCP reaches surface	RF quieting	XCP floating, RF transmitter working
		No quieting	RF-type failure
40 s	Probe released	Slight pop	Probe release squib has fired
	Probe transmitting data	Warbling sound	Wire is OK, probe working
		Regular warble	Probe falling and spinning
		Irregular warble	Probe stuck in surface unit - AF failure; noisy electrode
		No sound	Dead probe or wire broken - AF failure
		Spectral line near 350 Hz	Temperature data being transmitted
		Spectral line near 1200 Hz	Electric field data being transmitted
		Spectral line near 2400 Hz	Compass coil data being transmitted
6.5 min	Wire breaks	Audio signal stops	End of XCP data
11.5 min	XCP scuttled	RF quieting stops	Radio channel clear
Any	Other	Dropouts in audio data	Radio propagation problems Probe getting too far away

The electrical signals observed by the descending probe are converted to frequency-modulated voltages and telemetered via a pair of #39 XBT wires to the surface buoy. The buoy transmits these signals to the launch platform over the RF channel. The raw XCP data are received by the MK-10 signal processor, demodulated, and transferred to the HP-9020 computer, where they are processed, stored, and displayed. Watch the display of the profile on the HP-9020 CRT to determine if the data are good and listen to the VCR occasionally to make sure that it is receiving good data.

About 6 minutes after launch, the wire breaks as the probe passes about 1500 m depth. Useful scientific data end at this time, although the telemetry radio continues broadcasting until about 11 minutes after impact. At that time, the battery is shunted across a resistor—melting a hole in the flotation bladder, scuttling the surface unit, turning off the radio transmitter, and thus opening the channel for reception of the next profile. Note the times of wire breakage (AF off) and scuttle (RF off) on the XCP log sheet. If desired, enter the depth of the deepest XCP data and any comments about the deployment on the log sheet. Stop the VCR recording and enter the counter stop value

on the XCP log sheet. (Note: The acquisition program is not ready for the next drop until the data have been written to the cartridge tape and the diskette file has been closed.) Between drops, our acquisition programs can be paused or halted to prevent the cartridge tape from filling up with noise.

Switching HP-9144 cartridge tapes has to be done while the acquisition program is paused or halted. The VCR tape runs out near count 5750. Remember to reset the counter when a new tape is put in the VCR. About 30 XCP processed profiles fit on a floppy disk. Switching floppies is also best done when the program is paused or stopped.

The storage formats for the raw and processed XCP data from the HP-9020 acquisition program are listed in Appendix F.

6. XCP DATA PROCESSING

6.1 XCP Processing Programs

A set of XCP processing programs was written by John Dunlap in 1989. This set implements the functions of the old XCP processing program outlined by Sanford et al. (1982) but using simpler programs. The old program performed so many functions that it was difficult to maintain; many variants of it had emerged to do different things, and no one version existed for the general user. The new group of programs modularizes the processing and attempts to split it into functional groups. Modules are easier to understand and modify, encouraging clearer processing development in the future.

XCP processing is routinely done on an HP-9050 computer, but it should be readily adaptable to any UNIX system. The processing sequence can be broken down into the following steps: (1) set up a database of information specific to each drop (such as time of drop, location, and horizontal (F_h) and vertical (F_z) components of the Earth's magnetic field, (2) split the XCP data archived on the HP-9144 tapes by the Basic acquisition program into a separate file for each drop, (3) convert the 16-bit integer data into 32-bit floating-point values, (4) add the time-base information, (5) determine the exact turn numbers where the drop started and stopped and add this information to the database, (6) make baseline corrections, (7) produce profiles of east velocity, north velocity, and temperature as a function of depth or pressure, (8) grid the data, and finally (9) produce a standard plot.

This sequence is actually done in two parts. Both parts start with individual raw drop files. For efficient computer storage of the data, intermediate outputs are not retained. Part one takes the raw data to the "turn number" stage of processing. Turn numbers are used in subsequent processing to indicate where the drop starts and ends. Part two starts with the raw data, repeats the steps in part one with the exception of the turn step, and outputs gridded data. The XCP overview section of the programmer's manual (Appendix G) outlines the general processing sequence in more detail. As an example, the UNIX commands and programs necessary to process the Cadiz Expedition XCP data are listed below.

```
awk -f mag.in.awk prpos.out |
geomag |
awk -f mag.out.awk |
hdrmerge dropdatafile

awk -f extras.awk prpos.out |
hdrmerge dropdatafile

cadiztape -p channel < 9144.tapefile |
xcpsplit debug channel outtype filenamefile rawdirectory
```

```
xcpfloat < rawdirectory/drop |
xcpaddt xcpaddt.p |
xcpturn xcpturn.p dropdatafile

xcpfloat < rawdirectory/drop |
xcpaddt xcpaddt.p |
xcpblf xcpblf.p |
xcppro xcppro.p dropdatafile |
xcpgrid xcpgrid.p > griddirectory/drop

xcpplot griddirectory/drop | hpp7
```

A database, *dropdatafile*, is developed to contain processing parameters known to change from drop to drop. This database is an ASCII file, so it can be easily edited. Editing is needed when it is not possible to obtain correct values automatically (the start and stop turn numbers, for example, may be hard to determine for some drops for various reasons). Various programs modify and add to the database for items such as the geomagnetic field, start and stop turn numbers, etc.

The components of the Earth's magnetic field (F_h and F_z) at each XCP drop site are obtained by running the program *geomag* using times and positions from the underway log. Program *geomag* was obtained from the National Geophysical Data Center and replaces the program PADOC used by Sanford et al. (1982). Program *geomag* calculates the value of the seven magnetic field parameters for a specified date and location from a set of Schmidt quasi-normalized spherical harmonic coefficients read from an input model file. We currently use the International Geomagnetic Reference Field (IGRF90) model. The *awk* program is a UNIX command. In this application, *awk* uses the file *mag.in.awk* to reformat the log file into the format required by *geomag*. The *awk* program is run again with the file *mag.out.awk* on the output of *geomag* to format the results correctly for inclusion in the *dropdatafile* database. Program *hdrmerge* adds new entries or replaces previous entries in the database. Appendix H gives the programmer's manual entry for *hdrmerge*. In addition, extra parameters (such as XCP serial number and launch time) may be added to the *dropdatafile* (see Appendix H).

If XCP, XBT, and expendable sound velocimeter (XSV) data are all recorded on the same HP-9144 tape, a program, *cadiztape*, is run to separate out the XCP data. The output of *cadiztape* is piped to *xcpsplit*, which is used to divide the raw XCP data from the HP-9020 Basic acquisition program files into individual drop files. The programmer's manual information for *xcpsplit* is given in Appendix I.

Data written by the old processing program *tapetogpl* must be converted from floating point to 16-bit integer values at this stage in the processing sequence using the program *xcpftoi*. The programmer's manual information for *xcpftoi* is given in Appendix J.

Program *xcpfloat* converts the 16-bit integer data from *xcpsplit* (or *xcpftoi*) into 32-bit floating point values to make a standard format file. The programmer's manual entry for *xcpfloat* is given in Appendix K. A new program, *xcpdrtop*, has been added to process historical HP-9845 DXGET files from APL-UW that were archived on 800 bpi nine-track tape using the HP-9845 XARC4 program. Program *xcpdrtop* converts the XARC4 format to *xcpfloat* input format. Manual information for *xcpdrtop* is included under "Driver receiver" in Appendix G, XCP Processing Program Overview.

Program *xcpturn* is used to find the turn numbers where the drop starts and ends. It examines the record of rotation frequency during a drop to determine when the probe was released fr 1 the surface and when the drop terminated at the bottom. The turn number at half ιne average rotation frequency soon after the probe has spun up and the turn number for the last turn with good data are added to the *dropdatafile* database for later use by the program *xcppro*. The programmer's manual entry for *xcpturn* is listed in Appendix L.

Programs *xcpaddt, xcpblf,* and *xcppro* perform the actual processing. The purpose of *xcpaddt* is to develop a good time base so that correct depths can be assigned to the data. Problems can arise when the MK-10 microprocessor cannot keep up with noisy data. This program attempts to fix this so that shear can be estimated correctly and XCP profiles can be compared with other measurements or other XCP profiles. The programmer's manual entry for *xcpaddt* is given in Appendix M. Program *xcpblf* corrects the in-phase and quadrature data from the MK-10 by estimating and removing the contributions from a slowly changing baseline or average frequency of the signals. In addition, data from the MK-10 are converted to frequencies. The programmer's manual entry for *xcpblf* is given in Appendix N. Program *xcppro* accepts the corrected in-phase and quadrature FM frequencies as well as the XCP probe rotation frequency. All frequencies are in units of hertz. The standard input is typically produced by *xcpblf*. Program *xcppro* produces profiles of east velocity, north velocity, and temperature as functions of depth or pressure on standard output. Program *xcppro* executes Eqs. (23) through (30) of Sanford et al. (1982). The programmer's manual entry for *xcppro* is given in Appendix O. The output of *xcppro* is suitable for input to *xcpgrid*, which averages the data onto a uniformly sampled depth grid. Program *xcpgrid* can also produce vertical gradients of velocity and temperature. The programmer's manual entry for *xcpgrid* is given in Appendix P. Program *xcpplot* displays data from *xcpgrid* using standard scales on an HP-7550 pen plotter. The programmer's manual entry for *xcpplot* is given in Appendix Q.

6.2 XCP Depth Coefficients

The usefulness of the XCP depends in part on the accuracy of the estimated depth and temperature. This is especially true when combining the results from an XCP with

those from a CTD (conductivity, temperature, depth) cast for contouring and/or computing heat fluxes. The data collected during the Gulf of Cadiz Expedition presented the opportunity to verify the depth estimates of the XCPs by comparing the high-wavenumber structure of their temperature signals with those obtained by a Sea-Bird Electronics, Inc., CTD unit. This process also allowed estimation of the random errors and systematic offsets in both depth and temperature (Prater, 1991).

Based on the XCP/CTD comparisons, Prater found new depth coefficients for the XCP. The depth of the XCP is estimated by Sippican (1985) as a quadratic function of the fall time, such that

$$-z = z_0 + z_1 t + z_2 t^2 , \tag{1}$$

where z is the depth in meters (positive upward from the surface) and t is the elapsed fall time in seconds. The coefficients z_i of the quadratic polynomial are determined empirically. Table 3 gives the coefficients of the depth polynomial determined from Prater's analysis, along with those recommended by Sippican. The vertical velocity, w, of the XCP is obtained by the derivative of the depth equation, so

$$-w = z_1 + 2 z_2 t . \tag{2}$$

Table 3. XCP depth coefficients.

Coefficient	Sippican Mod 7	APL-UW, 1982 (Sanford et al., 1982, Eq. 28) Mod 6	Prater, 1991
z_0	0.0	3.1	4.68
z_1	4.276	4.544	4.377
z_2	−0.00063	−0.0006749	−0.00044

The XCPs fell 0.10 m s^{-1} faster than the manufacturer estimated at the surface, and 0.24 m s^{-1} faster at −1600 m. The error in the fall rate is important for XCPs, because the vertical fall rate w of the probe is used in the computation of the geomagnetic north velocity (Sanford et al., 1978). The error in the north velocity, v, due to an error in the fall rate is

$$\Delta v = \Delta w \, C \, \frac{F_h}{F_z} , \tag{3}$$

where F_h and F_z are the components of the Earth's horizontal and vertical magnetic field and C is a coefficient related to the shape of the XCP probe ($\approx$ 0.5). In the Gulf of Cadiz, F_h/F_z was 0.83, so Δv varied from 0.042 to 0.10 m s^{-1} throughout the probe's descent.

Figure 13 summarizes Prater's XCP depth analysis. The shaded region denotes the 2% accuracy in depth given by Sippican. The dashed lines are the results of the first two iterations, and the solid line is the deviation obtained using the revised XCP depth coefficients shown in Table 3. The rms variation in the depth offset is shown in panel c of Figure 14. The depth offset (panel b of Figure 14) varies from almost 0 at the surface to ~60 m by the end of a drop, near −1500 m depth.

The temperature offset (panel d in Figure 14) increases linearly with depth, with the XCPs being about 0.10° warmer at the surface and 0.22° warmer at the bottom of the drop (1500 m). A linear correction to the XCP temperatures was found such that

$$T' = T + T_0 + T_1 z \,, \tag{4}$$

where T' is the corrected temperature, T is the temperature computed using Dunlap's method described in Section 6.6, z is the depth in meters (positive upward), and the coefficients T_0 and T_1 are −0.10°C and 7.5×10^{-5}°C m^{-1}, respectively. The rms temperature variation, based on the corrected temperature, is approximately 0.1°C and has no trend with depth. It is unknown at this time whether the observed temperature trend with depth is due to a pressure effect on the thermistor, which should present itself as a linearly increasing error, or to a temperature effect on the circuitry, which, because of slow thermal diffusion, may be difficult to distinguish from a linear trend.

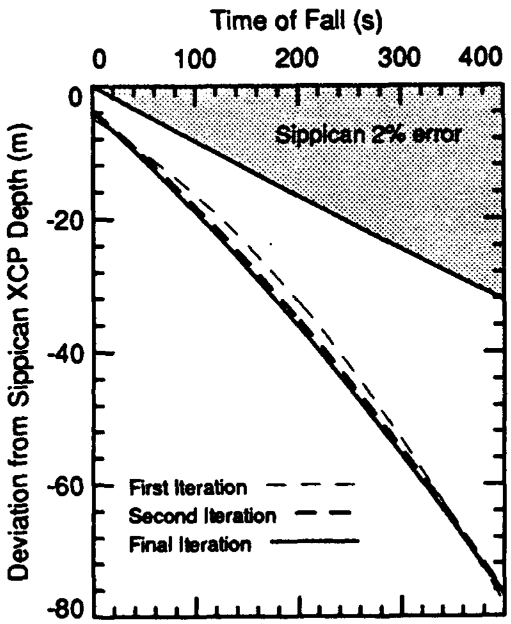


Figure 13.

Deviation in revised XCP depth from that given by Sippican, as computed from coefficients. The dashed lines are the initial iterations for the depth correction, the solid line is the final iteration (the result of the second iteration is almost indistinguishable from the final result). The shaded area is the 2% range given by Sippican as the accuracy of the XCP computed depth.

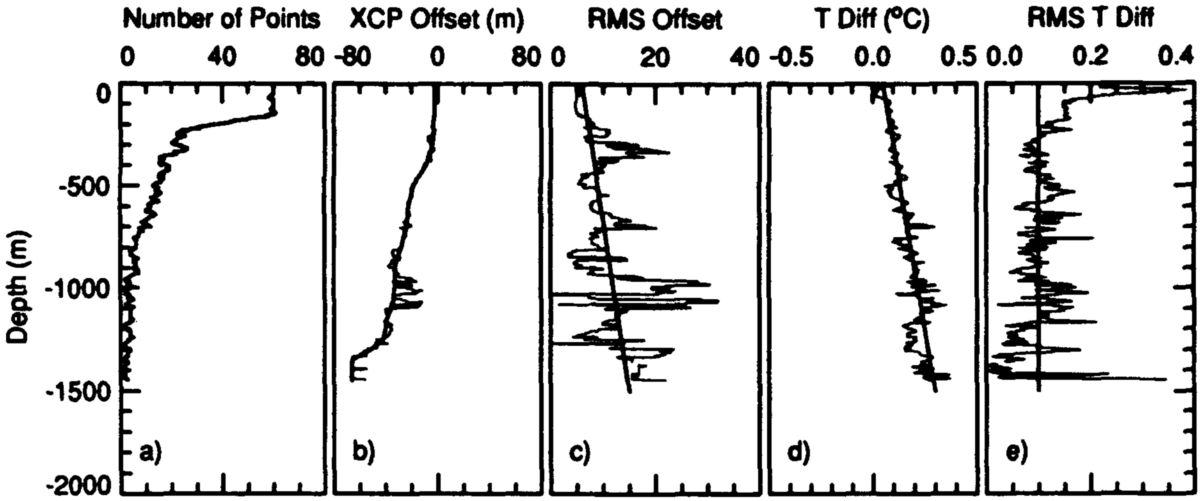


Figure 14. Combined result for all 67 XCP-CTD drop pairs in the Gulf of Cadiz. (a) The number of points used at each depth for determining the depth and temperature offsets. The number is less than the number of drop pairs since at some depths the correlation criterion was not achieved for individual drop pairs. (b) The computed depth offset. (c) The rms depth offset computed at each depth interval. The rms increases from 6 m at the surface to 15 m at −1500 m depth. (d) The temperature offset. (e) The rms temperature offset. The rms below the −200 m depth is approximately 0.1°C.

These results may be water mass specific, and further work is needed to determine whether the depth and temperature corrections are characteristic only of the warm and saline waters of the Mediterranean outflow. If possible, CTD casts should be done whenever XCPs are deployed to determine depth coefficients appropriate for the area being studied. However, if CTD data are not available, we recommend using Prater's coefficients until further studies can be carried out. Seaver and Kuleshov (1982) examine theoretical variations in the fall rates of XBTs; similar methods could be used to study XCPs. Internal waves may contribute to rms depth errors.

6.3 New Coefficients for XCP Processing

New coefficients to use in the processing programs for XCP system gains and phases were determined by Michael Horgan (Horgan et al., 1989). His work was prompted by examination of slowfall AXCP profiles obtained during the OCEAN STORMS experiment. Confirmation of his results was needed for the standard XCP before the new coefficients were considered valid for incorporation into the Cadiz data processing sequence. John Dunlap examined Horgan's findings for rotation rates of

14–18 Hz. The results of Dunlap's work are summarized by Kennelly et al. (1989b). The polynomial coefficients for gain and phase are listed in Table 4. The gains and phases are computed as $a_0 + a_1 f + a_2 f^2$. The a's at the end of the coefficient names denote amplitude; p's denote phase. Sanford et al. (1982) describe the meaning of each of the coefficient names.

These new polynomial coefficients describe the measured gains and phases as a function of rotation frequency for the entire XCP system from electrode and coil inputs to the digital output of the MK-10s. The original coefficients modeled only the analog section of the probe from the inputs to points just prior to the V/F converters, and only the phase dependence on rotation frequency.

We conclude that the new coefficients are more accurate than the original ones for predicting the MK-10 receiver output. However, the coefficients were determined for only one XCP board set and may be different for other boards. The MK-10 phases are a function of amplitude, and the variation of the coefficients as a function of board set should be investigated.

Table 4. Horgan's new polynomial coefficients of gain and phase.

	a_0	a_1	a_2
G_{efa}	23866.12044581	107.99111272898	−0.905827321
G_{cca}	1809.877761	−1.25653911	0.18856556
G_{cora}	898.89564739	0.453188608	0.0717425016
G_{efp}	−138.158938796	9.759010754	−0.180878978
G_{ccp}	29.826971133	10.265226263	−0.176531452
G_{corp}	56.552652832	7.783581145	−0.112472607
G_{evfa}	494.66025		
G_{evfp}	0		
G_{cvfa}	500		
G_{cvfp}	0		

6.4 A_{mean}

The copper compass coil wound coaxially around the electrode tubes is aligned such that its axis is nominally horizontal as the probe is falling. As the probe rotates, a time-varying potential difference is set up between the ends of the wire in the coil because the area of the coil facing the Earth's horizontal magnetic field (F_h) is changing with time. The strength of this potential difference is directly proportional to the area of the coil, the number of wire wraps, and the alignment of the coil axis with horizontal. Since the coil area and the number of wraps may change during manufacturing, we measure the amplitude of the potential difference, estimate F_h, and compute (wraps) × area and call it "area." As the probe falls, it might tilt because of the vertical shear in the ocean. This tilt causes the potential difference to change (the probe is now misaligned with the horizontal and is picking up some of the vertical magnetic field as well). All the estimates of area are averaged and called A_{mean}, and any deviation from this A_{mean} indicates tilt of the probe (Sanford et al., 1982). A representative value of A_{mean} for a particular data set should be determined prior to final processing. Previous work shows that a value of 695 cm^2 is appropriate for Mod 6 probes. Michael Horgan initially used this value in his calculations for Mod 7 OCEAN STORMS AXCPs, but later determined an A_{mean} of 667 cm^2 for those probes. The average A_{mean} value for all Gulf of Cadiz XCPs deeper than 1000 m was 662.3 $cm^2 \pm 8.2$ cm^2. A change of 1 cm^2 in area represents a change of 0.0027 m s^{-1} in the v component.

6.5 New C_2 Value for XCPs

Michael Horgan also determined a new value for C_2, a scale factor depending on the shape of the XCP that is used by the processing program *xcppro*. Using an A_{mean} of 695 cm^2 and the Sippican Mod 6 depth coefficients, Horgan obtained a value of $C_2 = -0.0127$. Because the A_{mean} and fall rate he used to compute C_2 were not appropriate for the Cadiz data set, John Dunlap converted Horgan's C_2 value to one suitable for the A_{mean} and fall-rate values determined for Mod 7 probes. Dunlap's method of conversion is outlined by Kennelly et al. (1989b). He determined C_2 to be -0.035.

6.6 XCP Temperature Processing

John Dunlap developed a simple method for using probe calibrations in our XCP temperature processing. Coefficients for a model of frequency versus thermistor resistance in the probe circuit were derived from the XCP calibrations values supplied by Sippican, Inc. Coefficients for a model of temperature versus resistance were derived from the Sippican thermistor specification. Dunlap's equation based on the model has been incorporated into the new XCP processing programs and is described here.

The Mod 7 XCP temperature circuit frequency was modeled as

$$F_t = \frac{1}{a\,C\,(R_s + R_t)}\,, \tag{5}$$

where $a = 4.4$, C is the value of the timing capacitor, R_t is the thermistor resistance, and R_s is the value of a resistor in series with the thermistor. Sippican supplies a calibration for each XCP which gives two frequencies, F_{t1} and F_{t2}, when two different resistors, R_{t1} and R_{t2}, are attached to the XCP in place of the thermistor. This is done on the unpotted circuit board before it is installed in an XCP. Resistors R_{t1} and R_{t2} are 16329 Ω and 4024 Ω, respectively, which corresponds to the Sippican thermistor specifications at 0 and 30°C.

These calibration frequencies and resistances can be used to determine R_s and C in Eq. (5) as follows:

$$R_s = \frac{F_{t1}\,R_{t1} - F_{t2}\,R_{t2}}{F_{t2} - F_{t1}} \tag{6}$$

and

$$C = \frac{1}{a\,F_{t1}\,(R_s + R_{t1})}\,. \tag{7}$$

Early probes used a timing capacitor with a tolerance of 10% and a potentiometer which was adjusted to give $F_t = 381$ Hz when $R_t = 7855$ Ω (the resistance specified for 15°C). It was realized that this procedure did not produce the same transfer function for all probes.

Sometime after April 1984, the method was replaced with a fixed 1% resistor (R_s) of 17,400 Ω, and a parallel combination of three capacitors was used to obtain C such that F_t was close to 381 Hz with $R_t = 7855$ Ω (see Sippican memorandum OM-7438, 1984). This was done to make the variability from probe to probe less than 0.2°C overall, including the thermistor variability, which is approximately 0.1°C.

The early probes had nominal component values of $R_s = 14{,}238$ Ω and $C = 0.027$ μF, whereas in new probes $R_s = 17{,}400$ Ω and $C = 0.02362$ μF. Note that any error in the model coefficient a is lumped in with C.

This circuit model can be used to process data from Mod 6 probes. In fact, the old Mod 6 method differs only in detail. Nominal calibration values for Mod 6 probes are $F_{t1} = 263.9$ Hz and $F_{t2} = 475.3$ Hz. The probes seldom deviate more that 0.2 Hz from those values, and thus individual temperature calibrations are not used.

It will probably not be necessary to use individual temperature calibrations with newer Mod 7 probes (neglecting the self-heating problems). They should be within 0.2°C of each other.

The model of temperature, T, given thermistor resistance, R_t is

$$T = \frac{1}{c_0 + c_1 \ln(R_t) + c_2 \ln(R_t)^2 + c_3 \ln(R_t)^3} - 273.15 . \tag{8}$$

To obtain the coefficients $c_0,\ldots,c_3$, we used the Sippican XBT thermistor specification for resistance R_t versus temperature T as data for a polynomial least-squares fit to

$$y = c_0 + c_1 x + c_2 x^2 + c_3 x^3 , \tag{9}$$

where $y = \dfrac{1}{T + 273.15}$ and $x = \ln(R_t)$. The maximum deviation from the fit when using data from −2 to 35.55°C was 0.01°C except at 35.00° and 35.55°C, where the points deviated by more than three standard deviations. When those two points were removed from the fitting, the following coefficients were obtained:

$$c_0 = 1.73323450654\times10^{-03} \tag{10}$$

$$c_1 = 8.755085297563\times10^{-05}$$

$$c_2 = 1.640669605119\times10^{-05}$$

$$c_3 = -5.098817533782\times10^{-07} .$$

The standard deviation of the residuals from −2°C to 34°C is 0.004°C. This is much better than the 0.2°C given in the XCP temperature specification.

Sippican Memorandum OM-7438 (1984) has coefficients for a fifth-order polynomial going directly from frequency to temperature for a nominal probe (R_s = 17,400 Ω and C = 0.02362 μF).

$$T = c_0 + (c_1 F_t) + (c_2 F_t^2) + (c_3 F_t^3) + (c_4 F_t^4) + (c_5 F_t^5). \tag{11}$$

The residuals have a standard deviation of 0.010°C when using the thermistor specification for −2 to 34°C. Examination of the residuals indicates that the fit used to obtain these coefficients included the faulty 35.00°C and 35.55°C points and that the standard deviation would probably decrease if those two values were removed during fitting.

Dunlap's method fit the data better than Sippican's although both fit much better than needed. Sippican's method can be improved by removing the 35.00° and 35.55°C points. Dunlap's method offers a simpler solution for the model coefficients. Sippican's method offers somewhat speedier computation once the coefficients are obtained.

7. XCP PERFORMANCE NEAR THE GEOMAGNETIC EQUATOR

Near the magnetic equator (Figure 15), the XCP's performance degrades owing to disappearance of the vertical component of the Earth's magnetic field. To understand what effects may be important near the magnetic equator, we examined the following simplified form of the equation for the magnetic north velocity component:

$$v_{xcp} = v - \bar{v}^* + \frac{F_h}{2F_z}\left[w - w' + \frac{vH}{L} + \frac{N}{lF_h}\right], \tag{12}$$

where

v_{xcp}	=	velocity measured by the XCP (m s^{-1})
v	=	magnetic north component of velocity (m s^{-1})
$\bar{v}^*$	=	conductivity-weighted vertically averaged velocity (m s^{-1})
F_h and F_z	=	horizontal and vertical components of the Earth's magnetic field (T)
w and w'	=	actual and assumed XCP fall rates (m s^{-1})
H and L	=	vertical and horizontal length scales of the flow (m)
N	=	electrode/electronic noise (V)
l	=	length of the electrode line (m).

Included in this equation is the desired velocity signal ($v - \bar{v}^*$), a fall rate term, a term dependent on the characteristics of the flow, and a noise contribution. The practical conversion of electric into velocity measurements involves approximations. Thus, the (v H)/L term arises as a first-order correction to the zeroth-order approximation. Away from the magnetic equator, this term multiplied by F_h/F_z is generally small (several centimeters per second) and mostly depth independent—hence it is usually neglected. As one approaches the magnetic equator, however, F_z begins to vanish. This causes terms scaled by F_h/F_z to appear larger near the magnetic equator than at midlatitudes; thus differences between the assumed and actual fall rate and electrode/electronic noise contributions will be amplified near the magnetic equator. Also, the term characterizing the flow, H/L, which is neglected at midlatitudes, may become important in the vicinity of the magnetic equator.

From comparisons of XCP profiles with ones from the recoverable free-fall profiler TOPS (Hayes et al., 1984) near the geomagnetic equator, we determined that the XCP performs well to within 1°–2° of the magnetic equator, corresponding to $F_z/F_h \approx 0.05$ in Figure 16. However, the north velocity component may degrade at latitudes greater than 2° from the magnetic equator owing to terms in the north-velocity equation that are not in the east-velocity equation. This comparison work is described in detail by Kennelly et al. (1986). The difficulties encountered with near-equatorial profiling arise from inaccurate

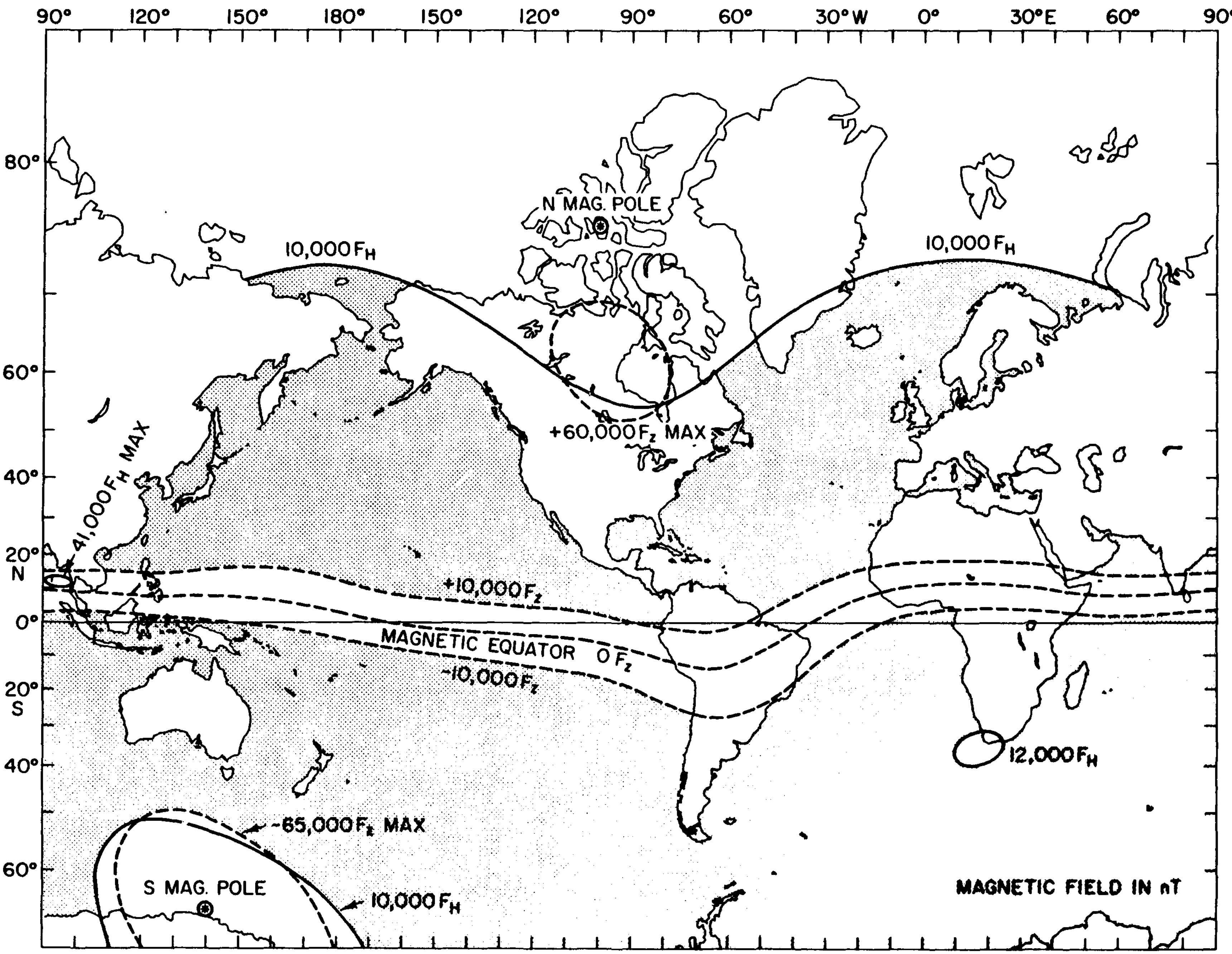


Figure 15. Location of zones of small F_z (magnetic equator) and small F_h (magnetic poles).

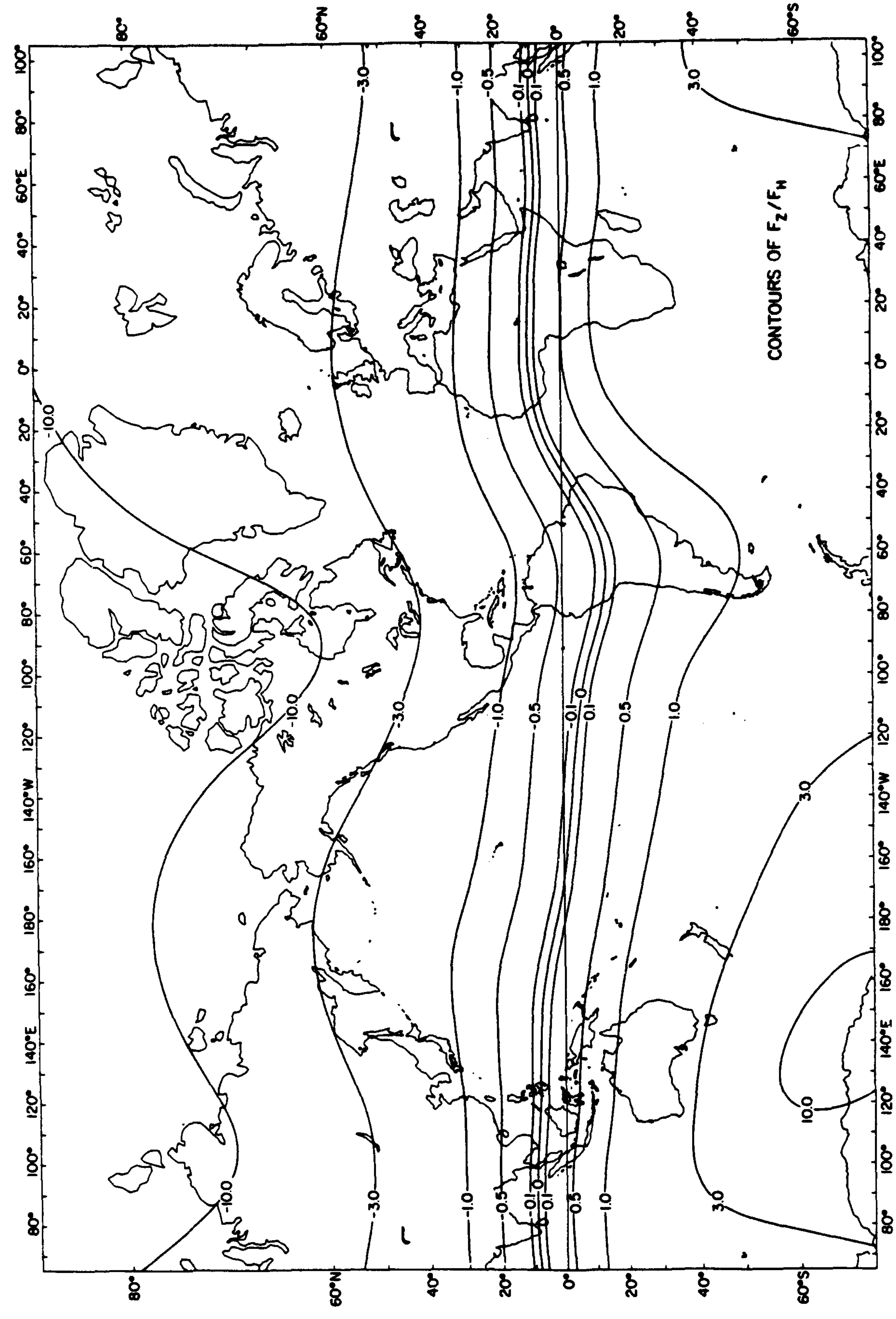


Figure 16. Global chart of F_z/F_h.

compensation of the fall-induced signals for electronic noise, vessel interference, and phase angle differences.

XCPs can be used near equatorial regions, but their performance will be degraded. We would expect errors of 10 cm s^{-1} at 1.5° or so from the magnetic equator. If observations are obtained outside the 0.05 F_z/F_h contour, data should be reliable.

8. XCP PERFORMANCE NEAR THE GEOMAGNETIC POLE

We have used XCPs up to a magnetic latitude of 85° (F_z/F_h = 10, Figure 16) and have had no problems. We do not know from experience what magnetic latitude will be too high for XCP operations. At very high latitudes, two effects should eventually degrade the signal. First, the compass coil signal will become increasingly small, as F_h decreases, until it can no longer be used. Fortunately, this is the strongest XCP signal, so very weak F_h values are required before it fails. Increasing the gain on the compass channel could extend the latitude range if this were a problem. Second, the effect of XCP tilt increases with increasing F_z/F_h, leading to increasing errors in velocity direction because of tilt. This error is intrinsic to magnetic compasses. Within a few degrees of the magnetic pole (Figure 15), magnetic compasses will not work, because the fluctuations in the magnetic field exceed its mean value. XCPs will fail there. Fortunately, this excludes only measurements in the Canadian Arctic Islands and on the Antarctic ice cap. The electric field signal increases at high latitude (with F_z), so measuring this signal is not a problem.

9. FAILURES AND FIXES

XCPs exhibit two failure modes which can be rectified during data processing. These two modes are half coil and reversed coil. Half coil means that a probe has a value of A_{mean} that is half the usual value (approximately 667 cm^2 for Mod 7 XCPs). The A_{mean} value is used in the XCP tilt correction. Reversed coil indicates that the probe was wired with the coil reversed. (Note: When the coil is reversed, it appears in the processing as if the electrodes were reversed since the reference is the coil.) It is thought that most of the wiring errors are coil wiring errors since those wires are easy to cross in the probe assembly.

If these two failure modes are noted, flags can be set by editing the *dropdatafile* and setting drop_halfcoil or drop_revcoil to 1. The flags alert the program *xcppro* to handle these drops as special cases. The documentation for *xcppro*, half coil, and reversed coil is given in Appendix O.

During the Cadiz work, we found 4 of 184 probes (2%) with reversed coils and 2 of 184 (1%) with half coils. When the software fixes were implemented, the data for these XCPs appeared usable. However, a subsequent analysis of XCP offsets indicated that one of the reversed-coil probes exhibited a larger offset in the v velocity component than other XCPs launched closely to it in space and time.

10. COMBINING XCP AND ADCP DATA

The XCP measures relative velocity; that is, the horizontal velocity is known only to a depth invariant offset (Sanford et al., 1982). This is expressed as

$$v_{xcp}(z) = v_{abs}(z) - \bar{v}^* \,. \tag{13}$$

The offset $\bar{v}^*$ (Sanford, 1971) is the conductivity-weighted vertical average of horizontal velocity. If the electrical conductance of the seabed is small compared with that of the water column, and if velocity and conductivity are not correlated with depth, then $\bar{v}^* \approx \bar{v}$, the barotropic water velocity. If $\bar{v}^*$ is known or can be estimated, then the absolute velocity can be determined from Eq. (13).

Acoustic Doppler Current Profiler (ADCP) data, used in conjunction with ship's position information (determined, e.g., from LORAN-C or GPS), provide a means of referencing XCPs to determine absolute velocities. The ADCP measures the velocity of the water at a given layer relative to the ship ($v_{w/s}(z)$), while LORAN-C, GPS, or other ship's navigation measurements give the velocity of the ship relative to the ground, that is, to Earth's fixed reference frame ($v_{s/g}$). The addition of these two measurements gives the "absolute," or "true," velocity of the water relative to ground [$v_{abs}(z)$]. Using measurements from the XCP, the ADCP, and ship's navigation, we find

$$v_{abs}(z) = v_{w/s}(z) + v_{s/g} = v_{xcp}(z) + \bar{v}^* \,. \tag{14}$$

If we let < > denote a vertical average over a range where the XCP and ADCP have data in common, and $\bar{\ }$ denote a time average over the period when the XCP is falling, then

$$< v_{abs}(z) > \; = \; < \overline{v_{w/s}(z)} > + \; \overline{v_{s/g}} \; = \; < v_{xcp}(z) > + \; \bar{v}^* \,. \tag{15}$$

Since the XCP falls rapidly (approximately 4.5 m s^{-1}), there is no extensive time averaging. Solving for $\bar{v}^*$, we find

$$\bar{v}^* = - < v_{xcp}(z) > + \left[< \overline{v_{w/s}(z)} > + \; \overline{v_{s/g}} \right] . \tag{16}$$

Using Eqs. (14) and (16), we obtain a vertical profile of absolute velocity, such that

$$v_{abs}(z) = v_{xcp}(z) - < v_{xcp}(z) > + \left[< \overline{v_{w/s}(z)} > + \; \overline{v_{s/g}} \right] . \tag{17}$$

To implement this method, the ADCP and XCP velocity data should be averaged over some vertical interval satisfying the following criteria:

(1) The high-vertical-wavenumber internal-wave signals in the instantaneous velocities obtained by the XCP but absent in the average ADCP velocities are averaged out.

(2) Both the XCP and the ADCP returned good data over the interval (for the ADCP data the percentage of good pings should be above 70%).

(3) The interval is deep enough to avoid mixed-layer and other near-surface effects.

As an example of a suitable vertical interval, Prater (1992) averaged Gulf of Cadiz Expedition data over 100 to 190 m.

A method given by Joyce (1989) can be used to compute $< v_{abs}(z) >$ by combining the ADCP and ship's velocities while correcting for possible errors in the ADCP alignment and the ship's gyrocompass. The calculations are very sensitive to ship's heading. Therefore the heading must be known accurately. Poor results may be obtained during turns, probably owing to the sluggish response of the ship's gyrocompass.

In Prater's implementation, he obtained a time series of $< v_{abs}(z) >$ from the continuous ADCP and ship's velocity data. Prater found it necessary to low-pass filter the data using a 3-dB point of 2 hours to reduce the velocity variance due to noise in the LORAN-C measurements. He then sampled the filtered $< v_{abs}(z) >$ time series at the times of XCP drops and used the resulting velocity values to modify $v_{xcp}(z)$. Because of the noise in the LORAN-C velocity estimates (rms error in velocity near 0.1 m s^{-1} most of the time) and the difference in the ADCP and the LORAN-C responses to changes in ship speed, Prater found the data difficult to use in his analysis of a Mediterranean water eddy. The LORAN-C data also suffered from low signal-to-noise ratios as well as small crossing angles between stations, which contributed to the degradation of the velocity estimates. (The cruise on which Prater's measurements were obtained occurred in 1988, prior to 24-hour GPS coverage.) LORAN-C coverage also was poor because of the geographic location of the cruise. However, the method does promise to be a useful way to reference XCP velocities, especiall ; in light of improved ship positioning techniques.

Figure 17 illustrates the promise of Prater's method. The figure shows selected pairs of XCP and ADCP profiles of east and north velocity from the Gulf of Cadiz Expedition. The dashed lines are an average of the ADCP data gathered while on station. The corresponding XCP data were obtained 20 minutes after the ship got under way from the CTD station. Note the good agreement between features in the ADCP and XCP profiles. For plotting, the XCP data have been offset by 0.1 m s^{-1}. Because the ship was on station, no LORAN-C data were used in this comparison. The dotted line represents the difference between the ADCP and XCP profiles, the estimate of $\bar{v}^*$. Note that $\bar{v}^*$ is relatively constant with depth.

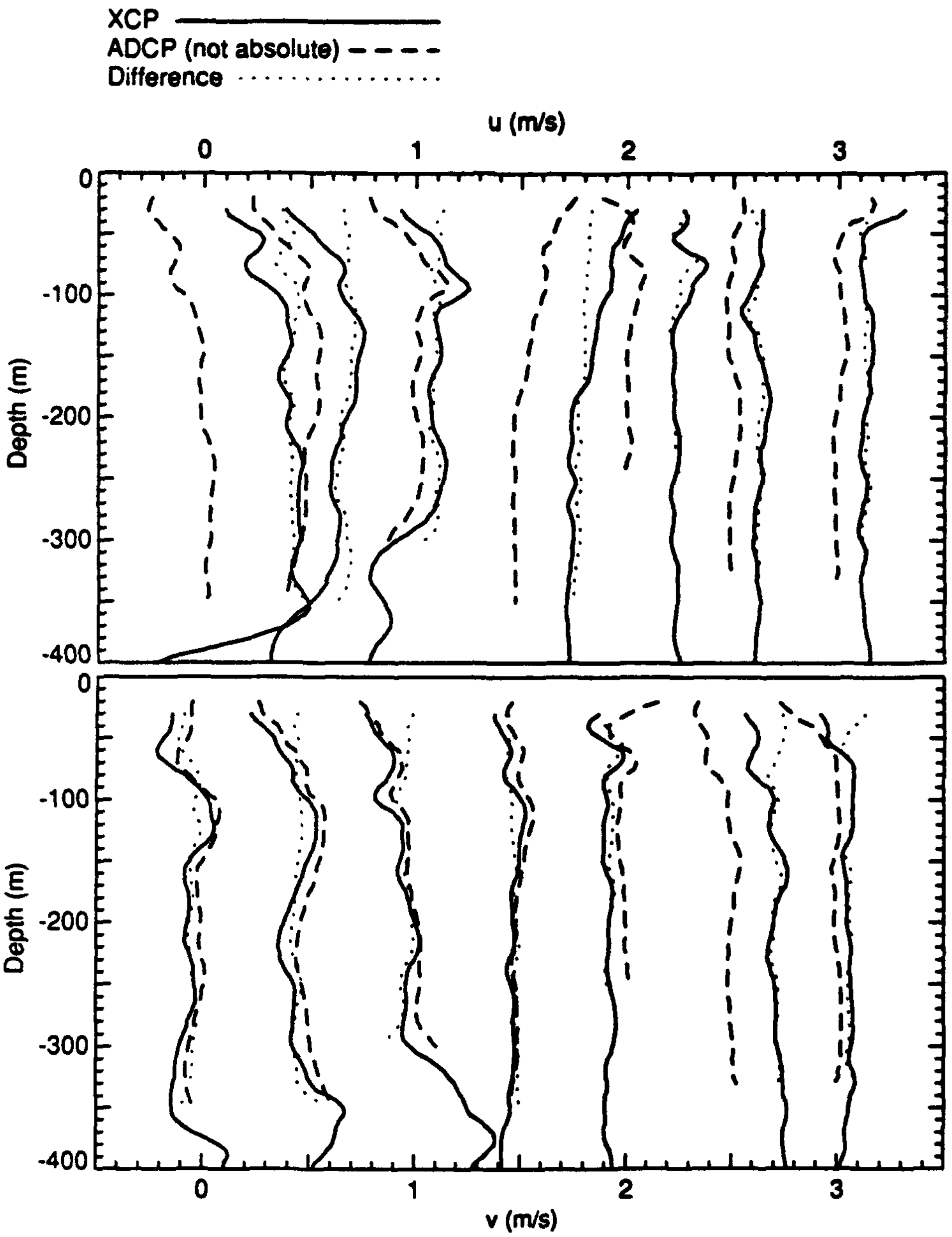


Figure 17. Pairs of XCP and ADCP profiles of east (top) and north (bottom) velocity from the Gulf of Cadiz Expedition. The dashed line shows the average of ADCP data while on station. The corresponding XCP data were obtained 20 minutes after the ship got under way from the station.

11. EFFECT OF FALL-RATE VARIATIONS ON NORTH VELOCITY

11.1 Introduction

If the fall rate, w, of the XCP is not well known, the computed north (v) velocity will be in error. In this section, we first examine the equations governing the v component of velocity and determine the potential size of the error. Then, we present an analysis of XCP data which illuminates the error in v. Finally, a model is proposed that explains the error in the XCP data in terms of variations in the XCP fall rate.

11.2 Theoretical Source of the Error

The equation for the geomagnetic eastward electric potential difference sensed by the XCP is (Sanford et al., 1982)

$$-\delta\phi = F_z l(v - \bar{v})(1 + C_1) - F_h l w(1 + C_2)\,, \tag{18}$$

where F_h and F_z are the Earth's horizontal and vertical magnetic fields, l is the electrode separation, C_1 and C_2 are XCP shape coefficients, and w is the vertical fall speed of the probe relative to the water. Thus, the eastward electric potential measured by the XCP is due in part to the northward motion of seawater through the Earth's vertical magnetic field, and in part to the vertical motion of the instrument through the Earth's horizontal magnetic field. The equation for v is given by

$$v = \bar{v} - \frac{\delta\phi}{F_z l(1 + C_1)} + w\frac{F_h}{F_z}\,\frac{(1 + C_2)}{(1 + C_1)}\,. \tag{19}$$

Let $w = w_o + w'$, where w_o is the empirical fall speed of the probe (see Section 6.2) and w' is any variation from the empirical value. The u velocity calculation does not depend on vertical velocity, so it is not affected.

Typical parameter values for the Cadiz data are

$F_z = 0.275$
$F_h = -0.315$
$C_1 = 0.970$
$C_2 = -0.035.$

Using these values, the expression for v becomes

$$v = v_{\text{true}} - 0.56w'\,. \tag{20}$$

Thus, if w' exceeds a few centimeters per second, this error in the v velocity may become noticeable.

11.3 Effect Found in Data

During analysis of XCP data from the Gulf of Cadiz Expedition, a "spike" was observed in the north (v) velocity component near 20 m on the vertical scale that did not appear in the east (u) velocity component (Figure 18a). A spike at the same vertical scale appeared in the rotation frequency (f_{rot}) of the XCP (Figure 18b). Profiles of f_{rot} show that the XCP turns 14 to 16 times a second (Figure 18c), but perturbations with vertical scales of 15 to 30 m (Figure 18d) are apparent. The rotation frequency is offset from probe to probe but has the same characteristic "s" shape. The vertical scale of the

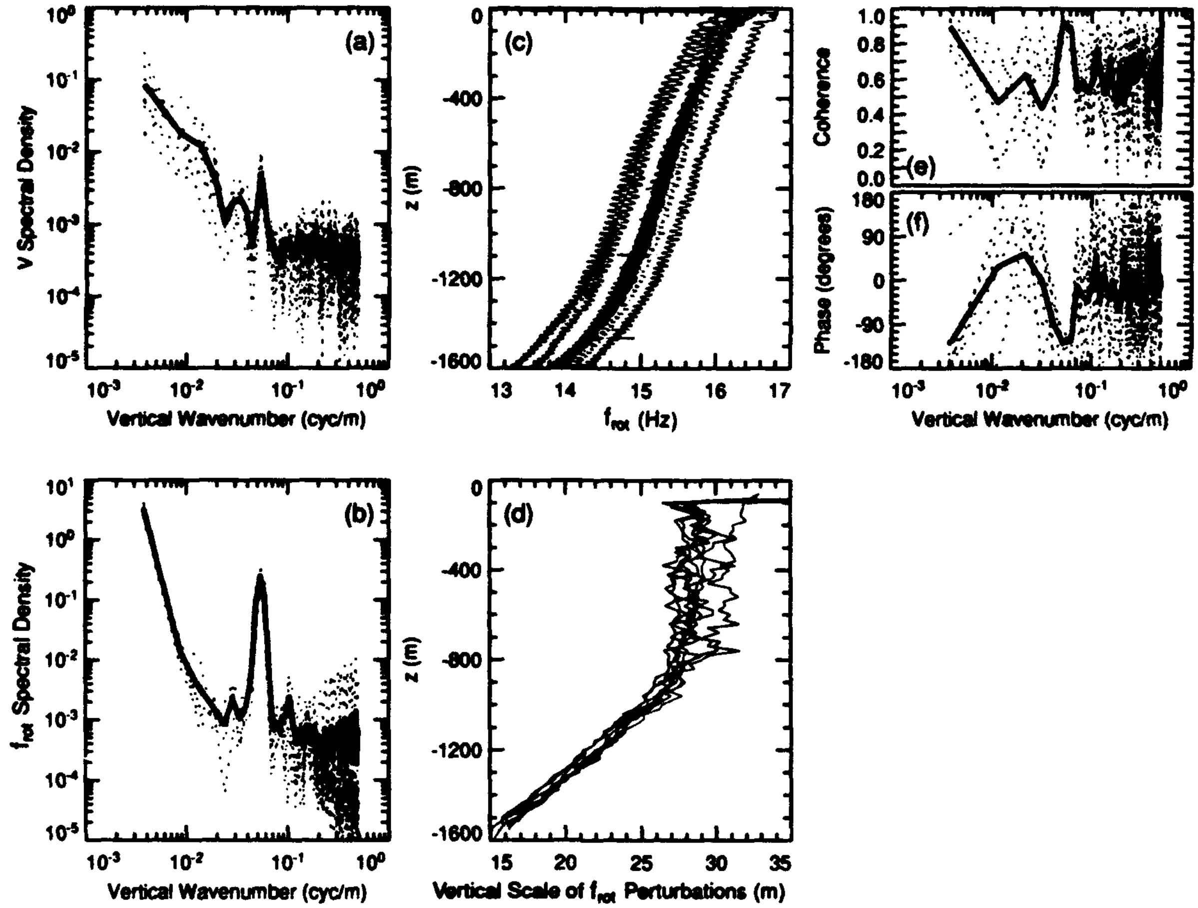


Figure 18. (a) Spectrum of v velocity as a function of vertical wavenumber computed for eight XCPs having data at 1-m intervals from −1200 to −1600 m depth (dots). The spectra were then averaged (solid line). (b) Same as (a), but for f_{rot}. (c) Profiles of f_{rot} for the eight XCPs. (d) Vertical scale of the f_{rot} perturbations. (e) Coherence of f_{rot} and v for the eight XCPs. (f) Phase of f_{rot} and v for the eight XCPs.

perturbations is variable about 30 m above 800-m depth, and tightly decreasing thereafter. The reason for the vertical structure of the perturbations is not known, but it may arise from how the wire comes off the XCP spool.

Values of f_{rot} and v are highly correlated ($r = 0.9$) at the vertical scale of the spike, with a phase difference of −125° (Figure 18e). Figures 18a, 18b, and 18e were made using data from depths of −1200 to −1600 m from eight XCPs. Repeating the spectral calculations at different depth intervals produces the same feature, but at a different vertical wavenumber.

11.4 Effect Explained by Model

A hypothesis for the source of the oscillations in f_{rot} and v is that the wire coming off the spool induces a (somewhat) periodic upward force, causing the probe to slow and speed its descent with the same periodicity. The fall-speed changes (the w' discussed above), in turn, cause a change in f_{rot} which, because of the probe's moment of inertia, is phase shifted.

A model, based on work by D'Asaro (1983), was used to understand the coupling between w and f_{rot} better. The linear and angular momentum equations are

$$m\frac{\partial w}{\partial t} = g\delta m - C_D A \rho w^2 - F_o \sin[f(z)] \tag{21}$$

and

$$\frac{\partial f_{rot}}{\partial t} = aw^2 - bf_{rot}w \, , \tag{22}$$

where (nominal values given in parentheses)

w	=	vertical velocity
m	=	probe mass (1.9 kg, with decrease of $1.00 \times 10{-4}$ kg m^{-1} due to wire loss)
g	=	gravitational acceleration (9.8 m s^{-1})
δm	=	excess mass of probe in water (1.0 kg, with decrease of 0.9×10^{-4} kg m^{-1} due to wire loss)
ρ	=	density of water (1024 kg m^{-3})
$C_D A$	=	drag coefficient times the probe's frontal area
F_o	=	amplitude of upward force exerted by the probe wire
f_{rot}	=	rotation frequency (16.26 Hz at the surface)
a	=	coefficient quantifying driving torque from drag on the probe's spin tabs
b	=	coefficient quantifying skin drag on the probe

The coefficients C_DA, a, and b were obtained from the near-surface equilibrium state of the XCP. The forcing, F_o, was set at 0.12 N to match observed amplitudes of f_{rot} and v (Figures 18a and 18b and 19a and 19b). This model reproduces the fall rate of the probe with depth (Figure 19c), the slow variation in f_{rot} with depth (Figure 19d), and the phase of f_{rot} and v (Figure 18e).

In summary, additional variance is input to the XCP v data at specific wavenumbers. The hypothesis that the v signal is caused by oscillations in the fall rate, w, is supported by a model of the XCP's dynamics. A preliminary correction to v can be

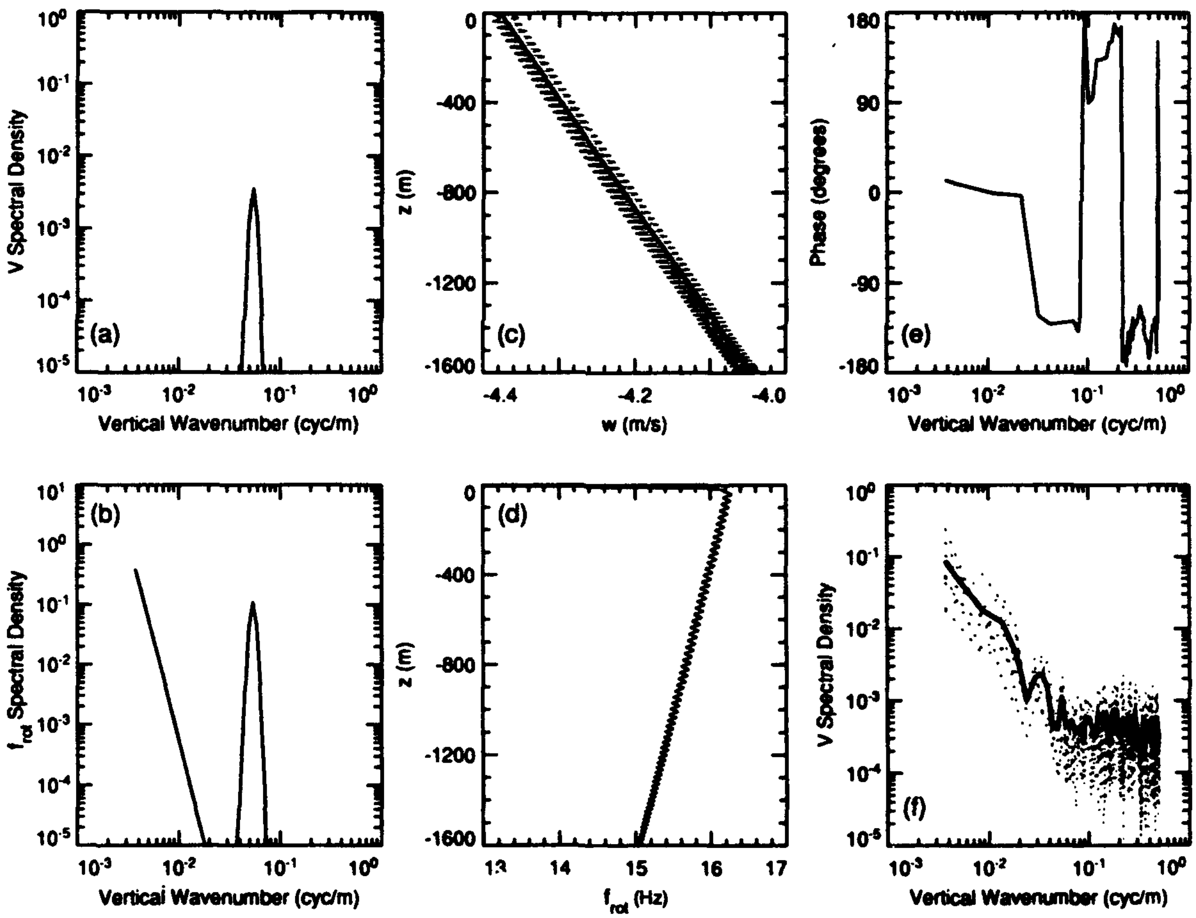


Figure 19. (a) Model spectrum of v velocity. (b) Model spectrum of f_{rot}. (c) Model (light line) and empirical (dark line) XCP fall rates. (d) Model f_{rot}. (e) Model phase of f_{rot} and v. (f) Spectrum of the corrected v velocity as a function of vertical wavenumber computed for eight XCPs having data at 1-m intervals from −1200 to −1600 m depth (dots). The spectra were then averaged (solid line).

made by using Eq. (19). The phase information between v (and therefore w) and f_{rot} is known from the data, and the magnitude of w can be estimated from the model. Figure 19f presents the v velocities from Figure 18a, corrected for the fall speed perturbations. Further understanding of the XCP motions is needed before more precise corrections can be made.

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APPENDIX B
Instrument Settings

Device Codes for HP9020 and peripherals:

Cartridge Tape Drive (HP9144)	:CS80,503,0
Floppy Disk Drive	:CS80,7,1
Internal Drive (Winchester)	:CS80,7,0

The VCR play time is about 2 hours; it ends at about 5750 on the counter. The VCR should be set to

Speed	Sp
MPX filter	Manual
Input	Line
Tape RemainN	NOR(mal)
Meter	Audio Level
	HiFi
Audio Select	Stereo
Audio Record Level	10 dB (when a drop is in progress)

The Sony PCM and ac Power Adapter should be set to

Mute	Off
Copy	Off
Input	Line
Tracking	Off

The MK-10 radio frequencies are

Channel 10	169.0 MHz
Channel 12	170.5 MHz
Channel 14	172.0 MHz
Channel 16	173.5 MHz

The Gold Line, Digital RTA should be set to

SCALE	3 dB/step
WEIGHT	FLAT
DECAY	FAST
AVG	on
PEAK	off
PK-HD	off
RTA	on
STORE	off
DISP	off
OPTION	off

The transmitted signals that will appear on the Spectrum Analyzer are

Temperature	0.35 kHz
Electric Field	1.20 kHz
Compass Coil	2.40 kHz
Carrier	8.00 kHz

APPENDIX C

XCP Launch Checklist

XCP LAUNCH CHECKLIST

DROP # __________ PROBE S/N ____________ MOD ____ CHANNEL ____
Initials __________ Expiration Date __________________________
Date ____________ Time ______________

PREDROP TESTS: These tests should be done long before the drop, so that if a replacement XCP is needed there is time. **DO NOT** remove the tapes and rubber band until just before launch.

RF TEST Check that the appropriate channel MK-10. is on. Turn the dial on the Patch Panel to the proper channel and listen using the headphones. You should hear noise. Be careful when attaching power to the XCP's, connecting power to the wrong wire will cause the airbag to inflate. There are two wires without insulation on them. One wire is much longer than the other, this one is the squib wire and should **NOT** have power applied to it. Be sure squib wire does not touch case.

SQUIB WIRE FREE ____________

The other wire is about 1 cm long. Using the 12 V power supply, connect the test clip (+12V) to the wire on the side of XCP and (-) to case. Turn on power supply. You should hear quieting.

QUIETING __________________

AF TEST Connect 3 pronged XCP test cable to the power supply. Be careful with the test probe, it carries 24 volts of power on it. Apply power to the test points on XCP. Be careful of the orientation of the test probe. Listen for XCP tones. You should also see three peaks on the spectrum analyzer for Temperature (0.35 KHz), Electric Field (1.2 KHz) , and Compass Coil (2.40 KHz).

XCP TONES ________

PEAKS: Temp _____ **EF** _____ **CC** _____

CC TEST Wave magnet over XCP electodes. Listen for warble.

CC wiggle ________________________________

Comments:

Be sure to fill out opposite side of this checklist!!!!!

DROP # _________ PROBE # __________

VISUAL EXAMINATION OF AGAR Remove the 2 pieces of tape over electrodes. Remove clear plastic that keeps the tape from touching the agar. Check the condition of the agar surrounding the electrodes and note below. If the probe is to be dropped immediately continue with checklist, otherwise replace clear plastic and tape over electrodes until launch time.

Agar Condition ____________________________

TO LAUNCH:

- Remove 2 pieces of tape over electrodes and attach to this log sheet below. Make sure the clear plastic that keeps the tape from touching the agar is also removed.

TAPES________

- Remove 2 pieces of fiberglass tape at lower end of unit and tape below.

TAPES________

- Remove rubber band and tape here.

RUBBER BAND _________

- Remind bridge to maintain radio silence.

APPENDIX D

XCP Log Sheet

XCP LOG

Drop # ____________ Probe S/N ____________ Channel ________
Initials ____________ Date ______________
VCR Tape No. ________ Counter Start ________ Stop __________
Floppy Disk No. _______ HP9144 Tape No __________

Times to the nearest 5 or 10 seconds (GMT):
Launch (RF on) ________________________________
Drop (AF on) ________________________________
Wire Break (AF off) ____________________________
Scuttle (RF off) ______________________________

Latitude Longitude

Launch Position _________________________ Method __________
_________________________ Method __________
_________________________ Method __________
Range and bearing to mooring _________________

==

Receiver used: _________________________ Configuration
Drop Quality: Good _____ Fair _____ Bad _____
Depth of deepest data ____________________
Fy ______________ Fz _________________
Simultaneous with _____________________
Ship speed __________ Heading _________
Wind (wrt ship): Speed _____ Heading ________
Waves: Height ___________ Period ________
Sea Surface Temp ________ Method __________
________ Method _________
Water Depth ______________

==

Comments: ____
____
____
____
____

APPENDIX E

Drop Checklist

DROP CHECKLIST

XCP [ ] XBT [ ] XSV [ ]

Drop # ____________

Partition ready for probe type 1 [ ] 2 [ ] 3 [ ]

- Check cable link to partition to find

MK10 Ch#	10 [ ]	12 [ ]	14 [ ]	16 [ ]
	part 1	part 1	part 2	part 3
Probe Ch#	10 [ ]	12 [ ]	14 [ ]	16 [ ]

Probe Serial # ____________

- Tapes and rubberband removed from probe [ ]
  (see XCP Checklist)

- Check cable link to partition to find

MK 9	Top [ ]	Bottom [ ]
	part 2	part 3

Probe Type (HP9020) ____________

- Answer questions on screen
- Load Probe
- Passed Prelaunch check (XBT only) [ ]

- Tape in VCR (count <5750) [ ]
- VCR recording [ ]
- Floppy in Drive [ ]
- HP9144 Cartridge tape running [ ]
- Drop probe and fill out XCP and underway logs [ ]

APPENDIX F

Storage Formats for XCP Data from HP-9020 Acquisition Program

F.1 Raw Data (as on HP9144 cartridge tape)

-- each record will look like

```
         |        |  2*17   true header
    n*   |  32*   | 30*17   data stream from MK10
         |        |  2*17   footer header
```

where n is any number and the true header is formatted

"#,5A,X,6D,22X";M$Hblen

where

M$ is the probe type ("7" or "7S") and
Hblen=32*(Nread+Nh1+Nh2), Nread=30*Nbps, Nh1=Nh2=Nbps=17
is the number of bytes following the true header.

The footer header contains the time stamp and the dropname formatted

"#,A,12Z.DDD,A,D,13A,XX";"T",TIMEDATE,"P",Part," "&Drop$

The data stream from the Mk-10 consists of noise and 17-byte strings D$

```
Dinp(3)=BINIOR(NUM(D$[4;1]),SHIFT(NUM(D$[5;1]),-8))
Dinp(5)=BINIOR(NUM(D$[8;1]),SHIFT(NUM(D$[9;1]),-8))
Dinp(6)=BINIOR(NUM(D$[14;1]),SHIFT(NUM(D$[15;1]),-8))
Dinp(7)=BINIOR(NUM(D$[6;1]),SHIFT(NUM(D$[7;1]),-8))
Dinp(8)=BINIOR(NUM(D$[12;1]),SHIFT(NUM(D$[13;1]),-8))
Dinp(9)=BINIOR(NUM(D$[10;1]),SHIFT(NUM(D$[11;1]),-8))
Dinp(10)=BINIOR(NUM(D$[16;1]),SHIFT(NUM(D$[17;1]),-8))

Din0(4)=BINIOR(NUM(D$[2;1]),SHIFT(NUM(D$[3;1]),-8))
```

and D$[1;1] is a sync byte = "G" or "B" if stream is in sync.

F.2 Processed Data (as on floppy diskettes)

The processed data are in BDAT files with OVERLAP, BUFFERED ON, MAX-BUFFS 4, and

filename Drop$=Mf$modayhrmin&"_"&VAL$(Part)

where Mf$="VF" for fast velocity drop and mo, day, hr and min are all 2-digit integers; e.g., VF06132043_1 represents a fast XCP drop started by partition 1 at 2043h on 13 June. These files contain a list of the integers

Iz, It, Iu, Iv, Ierr

where

```
Iz=z*10                                  ! z in m
It=SGN(T)*MIN(ABS(T),32)*1000            !T in °C
Iu=SGN(u)*MIN(ABS(u),320)*100            !u in cm/s
Iv=SGN(v)*MIN(ABS(v),320)*100
Ierr=SGN(Veler)*MIN(ABS(Veler),320)*100
```

APPENDIX G

XCP Processing Program Overview, *xcpover*

NAME

xcpover – overview of XCP processing

SYNOPSIS

```
awk -f mag.in.awk prpos.out | \
geomag | \
awk -f mag.out.awk | \
hdrmerge dropdatafile

awk -f extras.awk prpos.out | \
hdrmerge dropdatafile

cadiztape -p channel < kunzetapefile | \
xcpsplit debug channel outtype filenamefile rawdirectory

xcpsplit debug channel outtype filenamefile rawdirectory < dasarotapefile

remsh apl-em -n frd9t -n -b2048 | \
xcpdrtop > rawdirectory/drop

remsh apl-em -n 9845cat -r /dev/hp9895.0/drop | \
uxarc | \
xcpdrtop > rawdirectory/drop

xcpftoi [-dD] indir infile filenamefile rawdirectory

xcpfloat < rawdirectory/drop | \
xcpaddt xcpaddt.p dropdatafile | \
xcpturn xcpturn.p dropdatafile

xcpfloat < rawdirectory/drop | \
xcpaddt xcpaddt.p dropdatafile | \
xcpblf -c xcpblf.p dropdatafile | \
xcppro xcppro.p dropdatafile | \
xcpgrid xcpgrid.p | \
xcpplot | \
hpp7
```

DESCRIPTION

This set of programs implements the functions of old XCP processing programs *tapetogpl*, *xpro*, and *xgrid* using a number of simpler programs. XCP processing in *xpro* included so many functions that it was difficult to maintain. There were many variants to do different things and no one version existed for the general user. This group of programs modularizes the processing. An attempt was made to split the processing into functional groups. Hopefully modules are easier to understand and modify thus encouraging clearer processing development in the future.

The programs allocate main memory for the entire input file and output data so that multiple passes can be made on the data. This allows the programs to be written simply but does require more system resources. This should not be a great problem as the XCP files are not extremely large.

The data base of raw files is kept as small as possible by keeping it in 16 bit integers.

DROP DATA FILE

A small data base, *dropdatafile*, was developed for the processing parameters that are known to change from drop to drop. This data base is an ASCII file so that it can be easily modified by hand with an editing program. This is for the cases where it is not possible to obtain correct values automatically, e.g., the start

and stop turn numbers may be hard to determine for some drops for various reasons. Various programs modify and add to the data base for items such as the geomagnetic field, start and stop turn numbers, etc.

GEOMAGNETIC FIELD

The earth's magnetic field at each XCP drop site is obtained from *geomag* by using times and positions from the log. *Awk* uses *mag.in.awk* to reformat the log file into the format required by *geomag*. *Awk* is run again with *mag.out.awk* on the output of geomag to format the results correctly for inclusion in the *dropdatafile* data base. *hdrmerge* actually adds new entries or replaces previous entries in the data base.

Here is *mag.in.awk* used for the Cadiz data:

```
BEGIN {
      FS = "\t"
      print "y"
      print "/usr/local/geomag/igrf"
      print "9"
}
$7 == "XCP" {
      drop = $8
      date = $1
      lat = $2
      lon = $4
      yr = substr(date,1,2)    # year past 1900, e.g, 91 means 1991.
      mo = substr(date,3,2)    # month number, e.g., 3 for March
      da = substr(date,5,2)    # day number
      latd = substr(lat,1,2)   # integer degrees
      latm = substr(lat,4,5)   # minutes.hundredths
      lath = substr(lat,10,1)  # N or S
      lond = substr(lon,1,3)   # integer degrees
      lonm = substr(lon,5,5)   # minutes.hundredths
      lonh = substr(lon,11,1)  # E or W
      printf "%-8s 19%02d %02d %02d %2d %05.2f %s %3d %05.2f %s\n",\
            drop,yr,mo,da,latd,latm,lath,lond,lonm,lonh
}
```

Here is the version of *mag.out.awk* used for the Cadiz data

```
# mag.out.awk
# modifies the "geomag" batch output for the XCP data base
# this output should be piped into "hdrmerge" to modify the data base.
# see "mag.in.awk" for the "geomag" input

BEGIN {
      line = 0;
}
      {
      line ++;
# skip first two lines of geomag output
      if(line<3)
            continue;
      drop = $1;
      yr = $2;
      mo = $3;
      da = $4;
```

```
                latd = $5;
                latm = $6;
                lath = $7;
                lond = $8;
                lonm = $9;
                lonh = $10;
                fh = $11;
                fh *= 1.0e-5;
                fz = $12;
                fz *= -1.0e-5;
                magvar = $13;
                printf "# %s_lat %2d %05.2f %s\n",drop,latd,latm,lath;
                printf "# %s_lon %2d %05.2f %s\n",drop,lond,lonm,lonh;
                printf "# %s_fh %5.3f\n",drop,fh;
                printf "# %s_fz %5.3f\n",drop,fz;
                if(magvar < 0)
                      printf "# %s_magvar %6.1f W\n",drop,-magvar
                else
                      printf "# %s_magvar %6.1f E\n",drop,magvar
          }
```

EXTRA PARAMETERS IN DROP DATA FILE

Here is the version of *extras.awk* used for the Cadiz data. As many additional parameters as desired can be added in any manner for later use by later processing programs. The following two parameters are required by *xcppro* only to add them to the output file header. They are not used in any *xcppro* computations.

```
          BEGIN {
                FS = "\t"
          }
          $7 == "XCP" {
                drop = $8
                printf "# %s_serialno %s\n",drop,$29
                printf "# %s_launchtime %s\n",drop,$1
          }
```

XCPSPLIT

Xcpsplit is used to transfer the raw data from the HP-9020 Basic acquisition program files into separate files, one per drop. There is lots of extra rubbish in the raw files to be sure no data is thrown away during acquisition.

XCPFTOI

Data files from Eric D'Asaro's "tapetogpl" program are converted to the new 16 bit format by *xcpftoi.*

XCPFLOAT

Xcpfloat converts the 16 bit integer data from *xcpsplit* into 32 bit floating point values to make a standard GPL file. *Xcpfloat* can be run with the *-ms* option on the command line to make output suitable for input to Eric D'Asaro's "xpro3" or "xpro4" processing programs.

XCPTURN

Xcpturn is used to find the turn numbers where the drop starts and ends. These are added to the

dropdatafile data base for later use by *xcppro* and possibly other programs in the future.

PROCESSING

Xcpaddt, *xcpblf* and *xcppro* actually perform the processing previously done in *xpro*. *Xcpgrid* averages the data onto a uniformly sampled depth grid.

DISPLAY

Xcpplot displays data from *xcpgrid* using standard scales on the HP-7550 pen plotter. This program is used to make the books of standard plots. *Gpl(1)* can also be used for other more refined plotting.

CHECKING START AND STOP POINTS

The following C-shell command file will plot the output of *xcppro* near the beginning of a drop. This is useful to check that *xcpturn* found the correct points. The user may modify the *dropdatafile* by hand if these points seem incorrect.

```
#!/bin/csh
@ ref = `grep $drop"_turnhalf" dropdatafile | awk '{ print $3 }'`
@ start = $ref - 50
@ stop = $ref + 50
xcpfloat < split/xcp$drop | \
xcpaddt xcpaddt.p dropdatafile | \
xcpblf xcpblf.p dropdatafile | \
xcppro xcppro.p dropdatafile | \
pick diag=0 tag=turn.$ref start=$start stop=$stop | \
gpw zoom.cf
```

By replacing *turnhalf* above with *turnstop* the end of the drop may be plotted.

DREVER RECEIVER

HP-9845 DXGET files from the XTVP-DR (Digital Receiver or Drever Receiver) archived on 800 bpi nine track tape using the HP-9845 XARC4 program are transferred to the HP-9050 (apl-em) with *frd9t*, then *xcpdrtop* converts XARC4 format to *xcpfloat* input format:

```
#!/bin/sh
files="file1 file2 file3 ..."
frd9t -r -b2048 tape.id
for file in $files
do
      echo $file
      frd9t -n -b2048 | \
      xcpdrtop > rawdirectory/$file
done
frd9t -b2048 tape.end
```

HP-9845 floppy disks with raw XCP data from the XTVP-DR are copied to the HP-9050 (apl-em) using the attached HP-9895 dual floppy disk drive with:

```
#!/bin/sh
unit=0      # 0 for the left unit; 1 for the right unit.
files=`9845ls /dev/hp9895.$unit | awk '{print $1}'`
for file in $files
do
      echo "file=$file"
```

```
                9845cat -r /dev/hp9895.$unit/$file | \
                uxarc | \
                xcpdrtop > rawdirectory/$file
        done
```

uxarc converts the raw floppy disk data to XARC4 format suitable for input to *xcpdrtop*.

SEE ALSO

awk(1), geomag(1), hdrmerge(1), cadiztape(1), xcpsplit(1), xcpftoi(1), xcpfloat(1), xcpaddt(1), xcpturn(1), xcpblf(1), xcppro(1), xcpgrid(1), xcpplot(1), pick(1)

AUTHOR

John Dunlap, Applied Physics Laboratory, University of Washington

APPENDIX H

hdrmerge Documentation

NAME

hdrmerge – add or replace data in headers of GPL files

SYNOPSIS

hdrmerge filename

DESCRIPTION

Hdrmerge modifies the GPL header in *filename* according to another GPL header from standard input. If a header label from standard input does not exist in *filename* it is added to *filename*. If a header label from standard input exists in *filename* its value in *filename* is changed to that from standard input.

If the header labels **n_values** and **nquan** exist in *filename* and their product is greater than zero then floating point binary data is assumed to follow the header in filename. This data is rewritten after the modfied header in *filename*.

FILES

/usr/local/bin/hdrmerge

SEE ALSO

xcpover(1)

DIAGNOSTICS

BUGS

AUTHOR

John Dunlap, Applied Physics Laboratory, University of Washington

APPENDIX I

xcpsplit Documentation

NAME

xcpsplit – Split XCP HP-9020 BASIC acquisition files into separate drops

SYNOPSIS

xcpsplit debug partition outtype namefile outdir < basicfile

DESCRIPTION

xcpsplit separates XCP acquisition data into files, one per drop, suitable for the rest of the XCP processing programs. The XCP acquisition runs on an HP-9020A (HP-9000 model 520) computer running the HP-BASIC operating system. A master program, MASTER.READ (two versions: D'Asaro and Kunze), and up to three partitions, PART.READ (D'Asaro) or XCP.READ (Kunze), one per MK-10 receiver, are used in the multitasking environment.

The acquisition files were written on HP-9144 cartridge tape for Ocean Storms and Cadiz data but can also be written on other media. When *xcpsplit* is run the files have been copied to disk.

To transfer the HP-9144 tape data to the HP-UX system on the HP-9050 or HP-9020 mount the tape as a read-only file system and copy the files. The tapes cannot be mounted on the series 300 (faraday) computers; they have a series 500 file system and so must be mounted on a series 500 computer. Insert the write-protected tape, then type:

```
/etc/mount /dev/mtc3 /mtc -r
```

The HP-9000 model 550 HP-UX software revision 5.21 with the patched /etc/mount command emits the following erroneous warning message which should be disregarded.

```
/etc/mount: :Bad address
warning: /dev/mtc3 may not be clean
```

Use the following command to show the file name and size on the tape.

```
ls -l /mtc
```

A single file with a default name of "DATA" should be present. It may be as large as 16 Mbytes.

To copy the data from tape to disk use:

```
cp /mtc/DATA basicfile
```

To unmount the tape when finished.

```
/etc/umount /dev/mtc3
```

Now remove the tape from the drive by pressing the unload button and waiting until the *BUSY* light goes out.

It is important to NOT read the tapes more than a time or two as they will wear out with repeated accesses by the HP-UX system. This method of reading from a mounted tape in HP-UX is not easy on the streaming HP-9144 tape or tape drive. The drive repositions every 1 Kbytes since the operating system does not have the ability to stream the drive in the mounted mode. (Normally, tcio is used with cartridge tapes but that won't work in the mounted mode).

The files from Eric Kunze's version of the HP-9020 BASIC acquisition programs are piped through *cadiztape* before being processed by *xcpsplit*. This is to remove the XBT and XSV data which *xcpsplit* does not accept. For Eric D'Asaro's version *xcpsplit* accepts the original BASIC file directly.

If *debug* is greater than zero various diagnostics are printed on stderr. The higher the value the more is printed.

Data is extracted from the tape from *partition* which corresponds to the partition number *XCP_READ* ran under in *MASTER_READ*.

If *outtype* is **short** then files with integer data are produced. This is the recommended usage in order to save space. *Xcpfloat* converts these files for use by the rest of the processing programs. When *outtype* is **float** then a true GPL file is produced which is the same as that produced by the output of *xcpfloat* above. Both *outtype* **short** and **float** files have the same GPL header except for the **data_type** entries for each variable.

The *namefile* is a file which provides the correspondence between the original BASIC filenames and new filenames which are the drop number. If there is no entry in *namefile* the original BASIC filename is used for output. An example of one line in the *namefile* for the Cadiz cruise using Eric Kunze's BASIC acquisition program is:

```
# VF09112242_1 2466
```

An example for the Ocean Storms data using Eric D'Asaro's BASIC acquisition program is:

```
# Oct23/1036_1 2201
```

Output files with names found in *namefile* are created in the *outdir* directory.

drop in the GPL header is set the same as the output file name. This drop number is used later in *xcppro* to look up values in the *dropdatafile*.

An example for splitting partition 1 of tape number 6 of the Cadiz data is:

```
cadiztape -p 1 < SEP11.tape6 | xcpsplit 0 1 short fn.cadiz splitdir
```

FILES

/usr/local/bin/xcpsplit
/usr/tmp/xtmp.xxxxx where xxxxx is the process id of the job.

SEE ALSO

xcpover(1), cadiztape(1)

DIAGNOSTICS

BUGS

AUTHOR

John Dunlap, Applied Physics Laboratory, University of Washington

APPENDIX J

xcpftoi Documentation

NAME

xcpftoi – convert XCP files from floating to integers

SYNOPSIS

xcpftoi [-dD] indir lookup filenamefile outdir

DESCRIPTION

Xcpftoi converts files made by *tapetogpl* to files that have the same format as *xcpsplit* output files. All the data except the HP-9020 time stamp is converted from 4 byte floating point to 2 byte integers for more compact disk storage. *Xcpfloat* with the -ms option will quickly convert these files to input acceptable to the old *xpro3* and *xpro4* programs.

The -d option of *xcpftoi* turns on some diagnostic output on standard error. The higher the value of *D* the more is printed.

The input file name is made up by concatenating *indir* and *lookup*. *Lookup* is also used to look up the drop name in *filenamefile*. The output file name is formed by concatenating *outdir* and the drop name. *Filenamefile* is a GPL header style data base with one line per drop. An example for drops 2201, 2202 and 2203 is shown below:

```
# Oct23/1036_1 2201
# Oct23/1038_2 2202
# Oct23/1036_3 2203
```

This will work with the following example command line:

```
xcpftoi ~axcp/oceanstorms/raw Oct23/1036_1 fn.os ftoi
```

to read the file ~axcp/oceanstorms/raw/Oct23/1036_1 and write the file ftoi/2201.

The *filenamefile* for oceanstorms, fn.os, was formed by the following *awk* job:

```
P=/e/users/axcp/oceanstorms/param
rm -f awk.out
for i in `cat list.os`
do
     awk -f fn.os.awk < $P/$i  >> awk.out
done
```

where "list.os" is a file containing the drop numbers (parameter file names) and "fn.os.awk" contains:

```
/^# flight /          { flight=$3 }
/^# drop_realtime /   { file=$3 }
/^# drop /        { drop=$3 }
END   { printf "# %s/%s %s\n",flight,file,drop }
```

FILES

/usr/local/bin/xcpftoi

SEE ALSO

xcpfloat(1), xcpsplit(1), xcpover(1)

DIAGNOSTICS

BUGS

AUTHOR

John Dunlap, Applied Physics Laboratory, University of Washington

APPENDIX K

xcpfloat Documentation

NAME

xcpfloat – converts xcpsplit output to GPL format

SYNOPSIS

xcpfloat [-s|-ms]

DESCRIPTION

Xcpfloat reads standard input and writes standard output. The input is assumed to come from *xcpsplit* output and the output is a GPL file. The data base is usually kept as *xcpsplit* output files which are 16 bit integers to conserve space. All the processing programs use floating point values in the files.

The **-ms** option converts the time variable from seconds to milliseconds in order to be compatable with the old *xpro3* and *xpro4* programs. The **-s** option (default) leaves time output in seconds.

FILES

/usr/local/bin/xcpfloat

SEE ALSO

xcpover(1)

DIAGNOSTICS

BUGS

AUTHOR

John Dunlap, Applied Physics Laboratory, University of Washington

APPENDIX L

xcpturn Documentation

NAME

xcpturn – determine where XCP drop starts and stops turning

SYNOPSIS

xcpturn paramfile dropdatafile [infile]

DESCRIPTION

Xcpturn examines the rotation frequency record of a drop to determine when it was released from the surface and when the drop terminated at the bottom. The turn number at half the average rotation frequency soon after it has spun up as well as the turn number for the last turn with good data are added to the *dropdatafile* data base for later use by *xcppro(1)*.

Standard input is used for the input unless the input file, *infile* is specified.

paramfile contains some run time parameters in GPL header format as described below.

debug is set to 0 normally. For more diagnostic output increase the value.

timeused
should be set to tmaster.

rotfmin, rotfmax
are the minimum and maximum rotation frequencies allowed in the computations.

mavg, diffmax, nokneed
are used to determine the end of the drop. The drop is considered to stop at the last turn where the difference between its rotation frequency and the average for the previous **mavg** turns is more than **diffmax** for **nokneed** turns in a row.

The following is an example *paramfile*.

```
# debug 0
# timeused tmaster
# rotfmin 2
# rotfmax 20
# mavg 20
# diffmax 1
# nokneed 20
```

An example of the two records added to the *dropdatafile* for drop 2208 are:

```
# 2208_turnhalf 740
# 2208_turnstop 5947
```

FILES

/usr/local/bin/xcpturn

SEE ALSO

xcpover(1)

DIAGNOSTICS

BUGS

The start of the drop depends on the **downturn** value in the header of the input file. This is computed in *xcpaddt(1)*. The average from 30 to 50 turns past **downturn** is used to get the average rotation frequency near the beginning of the drop. This is not good practice – the code should be put all in this program. And the use of magic numbers is poor.

The end of drop algorithm works fairly well for the drops that hit the bottom but does not find the point where the wire starts to stretch just before breaking when the probe spool is exhausted. Thus there are many times 20 turns of data near the end of a deep drop where the fall rate is not known and so the north

component of velocity is not computed correctly.

The data during the period the rotation frequency is decreasing linearly is normally removed by hand by examining a plot of the *xcppro rotf, u* and *v* output for the 100 turns centered on the turnstop computed by xcpturn. The dropdata file is then modified manually.

Slow fall probes are not handled yet.

AUTHOR

John Dunlap, Applied Physics Laboratory, University of Washington

APPENDIX M

xcpaddt Documentation

NAME

xcpaddt – computes the time base for XCP raw data

SYNOPSIS

xcpaddt paramfile dropdatafile [infile [outfile]]

DESCRIPTION

Xcpaddt reads standard input or *infile* and writes standard output or *outfile*. The *paramfile* and *dropdatafile* contains several parameters needed. These are entered in the GPL header format.

The goal of this program is to develop a good time base for the data samples from the MK-10 receiver so that correct depths can be assigned to the data. This is needed to estimate shear correctly as well as to compare XCP profiles to other measurements or other XCP profiles. Three time bases are available as input: the incremental rotation period in the MK-10 "G" (good) packets, the "elapsed" time in the MK-10 "B" (bad) packets and the HP-9020 time stamp of the arrival of every 30th packet.

The code is modified to operate in the time domain from the depth algorithm written by Eric D'Asaro in his xpro4.c. This version may not operate entirely correctly as it has not been tested on drops with RF dropouts.

PARAMETERS

The *paramfile* requires the following:

debug is set to zero normally. For more diagnostics increase its value.

tag if present is used to override the default tag of xcpaddt.

dtmin, dtmax
are the minimum and maximum allowed time difference between the sum of the rotation periods from "G" packets and the elapsed time from "B" packets.

dtbad is the average time assumed for a "B" packet when the above criteria fails. It has been empirically determined to be 0.118 s.

rotfmin, rotfmax
are the minimum and maximum values of rotation frequency considered in the *tfall* and *tquit* tests below.

tfall is the time required with all rotation frequencies between the above limits and with all "G" packets to determine the point the XCP starts to fall.

tquit is the duration of continuous bad packets or rotation frequencies continuously outside the above limits to determine when the XCP stops turning. It generally indicates a point for quitting which is significantly later than the drop actually stops turning. See xcpturn for a better method.

tquit determines *finishturn* and *finishtime* in the output header but these are not used in any later processing so *tquit* has no particular use.

tspinup is a time delay after the XCP started turning before the *tquit* criteria above is used.

rotferrmax
is the threshold value of the maximum value of the forward or backward first difference of rotation frequency above which the time base, *tsampf*, is corrected by linearly interpolating between points where the differences are less than *rotferrmax*.

The following is an example of a *paramfile*.

```
# debug      0
# tag      xcpaddt
# tfall        2
# tquit        0.5
# dtmin      .05
# dtmax      .2
```

```
# dtbad        .118
# rotfmin   8
# rotfmax   20
# rotferrmax      0.5
# tspinup   3.5
```

The *dropdatafile* may contain a *dropno_playspeed* entry for this drop which is the ratio of the playback tape speed to the record tape speed. It defaults to 1.0 if an entry cannot be found for this drop.

FILES

/usr/local/bin/xcpaddt

SEE ALSO

xcpover(1)

DIAGNOSTICS

BUGS

AUTHOR

John Dunlap, Applied Physics Laboratory, University of Washington

APPENDIX N

xcpblf Documentation

NAME

xcpblf – XCP baseline correction and conversion to frequencies

SYNOPSIS

xcpblf [-c] paramfile dropdatafile [infile [outfile]]

DESCRIPTION

Xcpblf corrects the in-phase and quadrature data from the XCP receiver by estimating and removing the contributions from a slowly changing base line or average frequency of the signals.

In addition the data from the receiver is converted to frequencies.

The **-c** option is used to chop off the profile at **turn_half** and **turn_stop** which are obtained from the *dropdatafile*.

The *dropdatafile* is the same one used by xcppro.

The *paramfile* has several parameters described below in GPL header format.

debug is set to 0 normally. Higher values produce more diagnostic output.

tag if present is used to override the default tag of **xcpblf.**

blctype is the baseline correction type. There are presently four options, **none, original, 2back, bottom.** The **none** option applies no corrections. The **original** option uses the method in the XTVP report, APL-UW 8110. The **2back** option solves the equations in the report assuming only a linear baseline model (E=0) and only using the present and previous rotation. This option allows one to calculate velocities on the last turn as the XCP hits the bottom. The **bottom** option is like **original** except the last point which is like **2back** in order to process as close to the bottom as possible.

s1, s2, s3
are the inverse of the multiplication ratios of the phase lock loops for the three channels, temperature, electric field and compass coil.

rotfmin, rotfmax
are the minimum and maximum rotation frequency used to determine if the data are reasonable. Rotation frequency data is set to a bad flag value if not in the above range.

An example of *paramfile* contents is below.

```
# debug     0
# tag       xcpblf
# blctype   bottom
# s1        .005
# s2        .0125
# s3        .025
# rotfmin   1
# rotfmax   20
```

FILES

/usr/local/bin/xcpblf

SEE ALSO

DIAGNOSTICS

BUGS

AUTHOR

John Dunlap, Applied Physics Laboratory, University of Washington

APPENDIX O

xcppro Documentation

NAME

xcppro – XCP processing

SYNOPSIS

xcppro paramfile dropdatafile [infile [outfile]]

DESCRIPTION

xcppro accepts the corrected in-phase and quadrature carrier frequencies as well as XCP probe rotation frequency. All are assumed to be the estimated probe frequencies with units of hertz. The *infile* or standard input is typically produced by *xcpblf. xcppro* produces profiles of east and north velocity components and temperature as a function of depth and pressure on standard output or *outfile*. The output of *xcppro* is suitable for input to *xcpgrid.*

paramfile has the processing parameters and other files of parameters to use. All the parameter files use the *mkhdr* format similar to the GPL header for the data files. If a parameter is present in more than one parameter file it's value is taken from the first parameter file. The parameter file on the command line is considered before the rest.

dropdatafile contains processing parameters specific to each drop such as the earth's magnetic field, position and start and stop points for processing. This data is maintained by other programs and *xcppro* reads from it. It is an ASCII file so any text editing program can be used to change values. See *xcpturn(1)* and *hdrmerge(1).*

One *dropdatafile* is maintained for each cruise or group of drops. Each parameter is prefixed by the drop name. Usually the drop name is just the sequential number of the XCP launch.

xcppro implements the part of the processing that is specific to the probe. It executes equations (23) through (30) of the XCP report, APL-UW 8110.

There is no filtering option in *xcppro* as that is typically done in *xcpgrid.*

PARAMFILE CONTENTS

debug is set to 0 for no debugging messages on stderr. The higher it is set the more messages are printed.

paramfiles
specifies a list of additional parameter files to be used to supply the parameters to *xcppro.*

timeused
should be set to tmaster.

efccp0 efccp1
are the intercept and slope as a function of rotation frequency respectively of the differential phase between the electric field and compass coil channels of the digital receiver used. I have not set these to anything but zero.

amean is the area in cm^2 times the number of turns of the compass coil. In old programs it was actually computed as the average value of the area. Now it is entered as a constant. For Mod 6 probes a value of 695 seemed to be correct. The value 667 has been determined by Michael Horgan for the Ocean Storms AXCP probes. This may hold for all Mod 7 probes.

gcca gcora gefa
are the polynomial coefficients as a function of rotation frequency of the amplitudes of the gains of the compass coil, correction and electric field channels before the voltage to frequency (V/F) converters in the probe. Each set of coefficients is entered on one line. The zeroth order coefficient is first with the others following. There may be up to 6 coefficients for up to a 5th order polynomial.

For example if three coefficients are entered for **gcca**, *gcca0, gcca1, gcca2,* and the rotation frequency is *rotf* then the compass coil amplitude used in the calculations is *gcca0 + gcca1 * rotf + gcca2 * rotf^2.*

gccp gcorp gefp
are polynomial coefficients used to compute the phases of the probe channel gains as a function of rotation frequency in the same fashion as **gcca, gcora** and **gefa** above.

esep is the distance in cm between electrode ports. It is also the diameter of the probe.

c1 + 1.0 is the amplification factor of the electric potential sensed across the probe because the electric currents must go around the insulating body. The usual value used for **c1** for an XCP is 0.97. It depends on the shape of the body. For an infinite cylinder **c1** would be 1.0. See the EMVP report, WHOI-74-46, eqn. III-11.

c2 + 1.0 is the factor controlling the addition of vertical fall rate to the north component of velocity. Usually **c2** is assumed to be -0.02 for XCP probes. See the EMVP report, WHOI-74-46, eqn. III-11.

gevfa gevfp
are the amplitude and phase of the gain of the voltage to frequency converters for the electric field channel.

gcvfa gcvfp
are the amplitude and phase of the gain of the compass coil voltage to frequency converter.

depthcal
are the coefficients of the depth polynomial as a function of time: *depth = depthcal0 + depthcal1 * time + depthcal2 * time^2*. Note that the depthcal values should be entered to obtain a positive downward depth. The programs compute "z" which is positive upwards with the same absolute value as depth but opposite sign.

prconv are the four coefficients used to convert depth to pressure using the following formula: *pr = depth / (prconv0 + prconv1 * depth + prconv2 * exp(depth / prconv3))* Setting the coefficients to zero inhibits the conversion.

tcalfreq
are the two frequencies of the temperature carrier (Hz) with resistances **tcalres** below.

tcalres are the two resistances (ohms) of the XCP thermistor at 0 and 30 degrees C respectively.

tcal are the four coefficients of the standard polynomial of logarithms of resistance to compute temperature from resistance. These coefficients were found by fitting the published temperature and resistance tables in the specification of the XCP thermistors: *T = 273.15 + 1.0 / (tcal0 + tcal1*ln(R) + tcal2*ln(R)^2 + tcal3*ln(R)^3)*.

tcor Specifies a linear correction as a function of depth to be added to temperature as computed above. *Correction = tcor0 + tcor1 * depth*

DROP DATA FILE CONTENTS

<drop>_**halfcoil**
is set to 1 to indicate that the processing should use half the usual amean in the tilt correction. If this parameter is not present in the *dropdatafile* it is assumed to be zero.

<drop>_**revcoil**
is set to 1 to indicate that the probe was wired with the coil reversed. If this parameter is not present in the *dropdatafile* it is assumed to be zero. Note that when the coil is reversed it actually appears to the processing as if the electrodes were reversed since the reference is the coil. It is thought that most of the wiring errors are actually coil wiring errors since those wires are easier to cross in the probe assembly.

<drop>_**fh** <drop>_**fz**
are the horizontal and vertical magnetic field at the drop site. The units are gauss which is 100,000 nT. The vertical magnetic field is negative in the northern (magnetic) hemisphere.

<drop>_**turnhalf**
is the turn number at which the probe comes to half its nominal rotation frequency. Depth is

computed according to time since the time at *turnhalf*.

<drop>**_turnstop**
is the last turn number with good rotation frequency. When a drop hits the bottom this turn is the last turn with good data. When the probe spool wire is exhausted the probe spin rate noticeably slows for the last 10 to 20 turns. This effect is also seen in the north velocity so the fall rate is probably changing. Presently the last 10 or 20 turns of deep drops are not processed correctly.

<drop>**_launchtime**
is the time the probe was released from the ship or aircraft. This time determines the position of launch which is assumed to be the same position of the drop. If there is significant wind this assumption will be incorrect.

<drop>**_serialno**
is the serial number of the probe.

<drop>**_magvar**
is the magnetic variation for use in coordinate rotation from the natural geomagnetic to geographic coordinates. No coordinate rotation is done in the standard processing: the U and V components are left in the magnetic coordinate system.

PARAMFILE EXAMPLES

The following is an example of parameter files used in testing with the Cadiz data. There is nothing magic about the file names or partioning of the data into the various files. It should be done to minimize the number of redundant entries.

The contents of xcppro.p are:

```
# debug          0
# paramfiles     deckbox.p probe.p depthcal.p tcal.p
# timeused  tmaster
```

The contents of deckbox.p are:

```
# efccp0    0.
# efccp1    0.
```

The contents of probe.p with Michael Horgan's new coefficients are:

```
# amean          667
# c1        .97
# c2        -.02
# esep           5.19
# gevfa          494.66025
# gevfp          0
# gcvfa          500
# gcvfp          0
# gefa      23866.12044581    107.99111272898   -0.905827321
# gcca      1809.877761 -1.25653911 0.18856556
# gcora     898.89564739      0.453188608 0.0717425016
# gefp      -138.158938796    9.759010754 -0.180878978
# gccp      29.826971133      10.265226263      -0.176531452
# gcorp     56.552652832      7.783581145 -0.112472607
```

The contents of depthcal.p with depth calibration and Cadiz pressure conversion follow as discussed in Prater(1991).

```
# depthcal        4.68  4.377 -0.00044
# prconv    0.9927      -2.55e-06   0.0073      -50.0
```

The contents of tcal.p follow. The values shown for tcor are for the Cadiz cruise as determined by Mark Prater.

```
# tcalfreq        285.3 449.1
# tcalres         16329 4024
# tcal      1.73323e-3  8.75509e-5  .64067e-5   -5.09882e-7
# tcor      -0.05       -1.25e-04
```

DROP DATA FILE EXAMPLES

The items for drop 2466 in the *dropdata* file are as follows. Not all of these items are used in *xcppro* computations but they are all required to be present for inclusion in the output header.

```
# 2466_serialno 871058
# 2466_launchtime 880911-224000
# 2466_lat 36 39.40 N
# 2466_lon 8 38.37 W
# 2466_fh 0.268
# 2466_fz -0.330
# 2466_magvar 5.9 W
# 2466_turnhalf 739
# 2466_turnstop 3479
```

FILES

/usr/local/bin/xcppro

SEE ALSO

xcpover(1)

BUGS

Please report them.

AUTHOR

John Dunlap, Applied Physics Laboratory, University of Washington

APPENDIX P

xcpgrid Documentation

NAME

xcpgrid – put XCP data on uniformly spaced depth grid

SYNOPSIS

xcpgrid paramfile [infile [outfile]]

DESCRIPTION

Xcpgrid reads from standard input or *infile* if it is present. It writes standard output or *outfile* if it is present. Input data is assumed to be from *xcppro*.

The *paramfile* has some parameters used in the processing:

debug is set to 0 normally. Increasing amounts of diagnostic output is written to standard error as *debug* is increased.

shearout
is a flag controlling the output of the shear variables. If 1 they are and if 0 they are not.

auxout is a flag controlling the output of area, rotf, efbl and ccbl. If 1 they are and if 0 they are not.

z0 is the initial value of the depth grid.

dz is the interval of the depth grid.

dzbin is the averaging interval for each output grid point. Usually this is set to two times **dz**.

zvar is the depth variable name from *xcppro*. It can be set to **z**, **depth**, or **pr**. **z** is positive up while **depth** and **pr** (pressure) are positive down. **z** and **depth** have units of meters while **pr** has units of dbar.

binmin is the fraction of a bin which must be averaged to obtain the last data point.

tmin, tmax
are the minimum and maximum temperatures allowed to be included in the output bins.

umin, umax
are the minimum and maximum velocity components (u & v) allowed to be included in the output bins.

rotfmin, rotfmax
are the minimum and maximum rotation frequencies allowed for any data to be included in the output bins.

zfiltrotf is the recursive filtering distance for averaging the rotation frequency.

maxdevrotf
is maximum deviation of rotf from the average rotation frequency. If the deviation is greater than **maxdevrotf** then no data is used from this scan.

An example of a *paramfile* follows:

```
# debug      0
# shearout   1
# auxout     1
# z0         0
# dz         2
# dzbin            6
# zvar             pr
# binmin     0.75
# tmax             35.0
# tmin             -3.0
# umax             2.0
# umin             -2.0
# rotfmax    20.0
```

```
# rotfmin   8.0
# zfiltrotf 3.0
# maxdevrotf      2.0
```

FILES

/usr/local/bin/xcpgrid

SEE ALSO

xcpover(1)

DIAGNOSTICS

BUGS

AUTHOR

John Dunlap, Applied Physics Laboratory, University of Washington

APPENDIX Q

xcpplot Documentation

NAME

xcpplot – standard plot for XCPs

SYNOPSIS

xcpplot [-d] [infile] | hpp7

DESCRIPTION

Xcpplot produces a standardized color plot of *xcpgrid(1)* output using the HP-7550 pen plotter. The dimensions are 10 inches high and 7 inches wide. The scales are 200 meters per inch for depth and 0.2 m/s per inch for velocity. Processing parameters which are specific to the drop are labeled on the plot. Others should be obtained from a listing of the parameter files for each program.

The -d option is used for debugging the program. *Infile* is the data file input. If *infile* is not present the input is taken from standard input. The standard output of *xcpplot* contains HP-GL plotter commands and is normally directed to the standard input of *hpp7*, the pen plotter spooler.

FILES

/usr/local/bin/xcpplot

SEE ALSO

xcpover(1)

AUTHOR

John Dunlap, Applied Physics Laboratory, University of Washington

APPENDIX R

List of Selected Symbols and Acronyms

ADCP	acoustic Doppler current profiler
AF	audio frequency
APL	Applied Physics Laboratory
AXCP	air-launched expendable current profiler
CC	compass coil
CTD	conductivity temperature depth
DAT	digital audio tape
EF	electric field
EM	electromagnetic
EMVP	Electro-Magnetic Velocity Profiler
FM	frequency modulated
F_h	horizontal component of Earth's magnetic field
F_z	vertical component of Earth's magnetic field
G_{cca}	CC gain (amplifier)
G_{cora}	gain of mixing circuit (CC through EF postamplifier)
G_{efa}	EF gain (amplifier)
G_{evfa}	EF gain (V/F converter)
G_{cvfa}	CC gain (V/F converter)
G_{efp}	EF circuit phase shift
G_{ccp}	CC circuit phase shift
G_{corp}	phase of mixing circuit (CC through EF postamplifier)
HP	Hewlett Packard
NOARL	Naval Oceanographic and Atmospheric Research Laboratory
NORDA	Naval Ocean Research and Development Activity
NRL	Naval Research Laboratory
ONR	Office of Naval Research
PCM	pulse code modulation
RF	radio frequency
SWR	standing-wave ratio
TOPS	Total Ocean Profiling System
V/F	voltage to frequency
VCR	video cassette recorder
VHF	very high frequency
VHS	video home system
UW	University of Washington
XBT	expendable bathythermograph
XCP	expendable current profiler
XSV	expendable sound velocimeter
XTVP	expendable temperature and velocity profiler

REPORT DOCUMENTATION PAGE

Form Approved
OPM No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
August 1993

3. REPORT TYPE AND DATES COVERED
Technical

4. TITLE AND SUBTITLE
An XCP User's Guide and Reference Manual

5. FUNDING NUMBERS
N00014-90-J-1100
N00014-84-C-0111
N00014-87-K-0004

6. AUTHOR(S)
Thomas B. Sanford, Eric A. D'Asaro, Eric L. Kunze, John H. Dunlap, Robert G. Drever, Maureen A. Kennelly, Mark D. Prater, and Michael S. Horgan

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Applied Physics Laboratory
University of Washington
1013 NE 40th Street
Seattle, WA 98105-6698

8. PERFORMING ORGANIZATION REPORT NUMBER
APL-UW TR 9309

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Office of the Chief of Naval Research
Department of the Navy
Ballston Center Tower #1
800 N. Quincy Street
Arlington, VA 22217-5000

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This report describes expendable current profiler (XCP) instrumentation, equipment testing procedures, data acquisition methods, and data processing. It also provides a guide to XCP field operations.

14. SUBJECT TERMS
Expendable Current Profiler (XCP), XCP, AXCP, Slowfall AXCP, XCP equipment, XCP testing, XCP calibration, XCP field operations, XCP data acquisition, XCP data processing, motional induction, current measurement, oceanographic instrumentation

15. NUMBER OF PAGES
101

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	N/A